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By-Goyal, K. C.; Swami, Piyush

Research Ideas for Science Projects.

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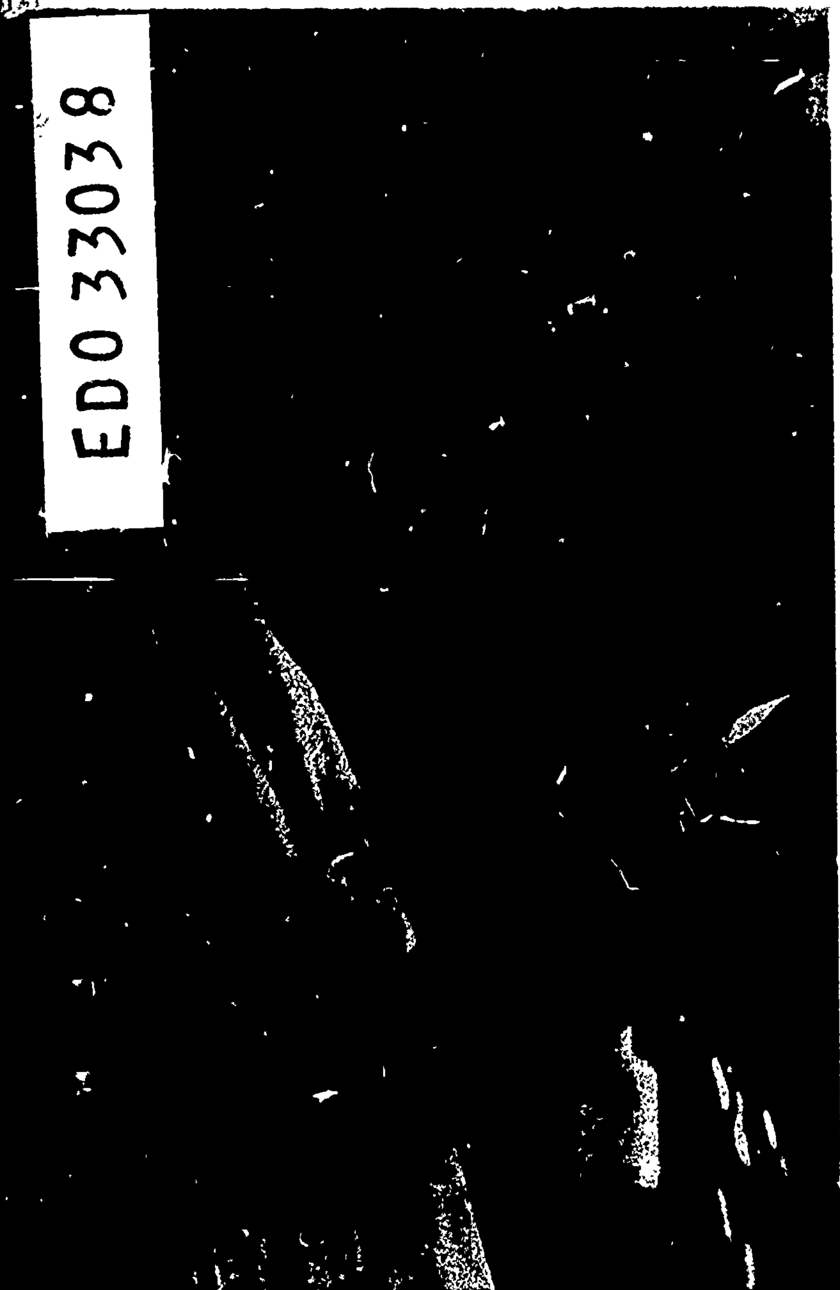
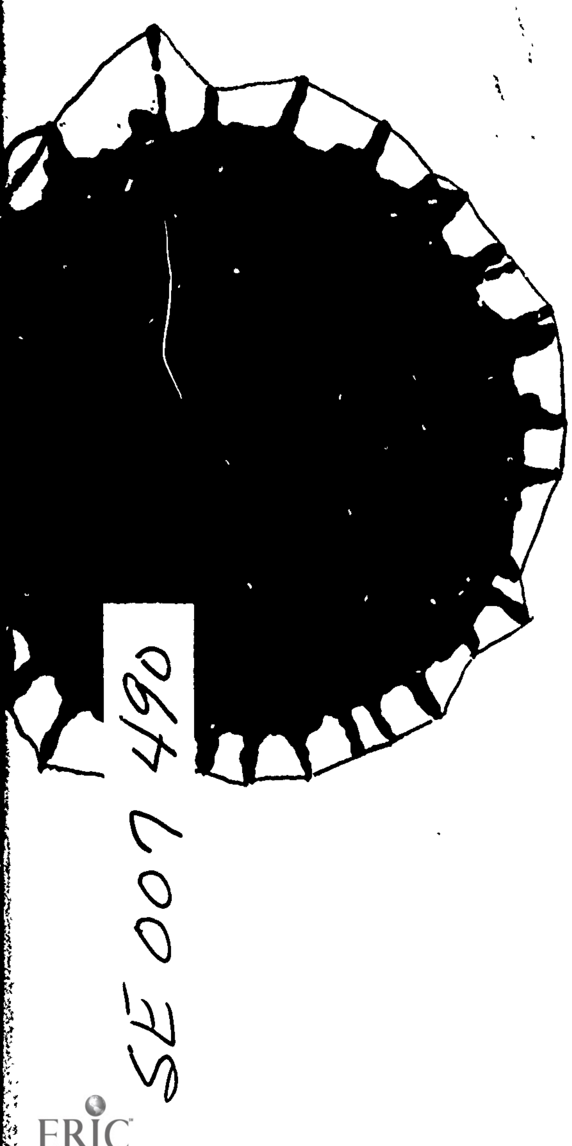
This book was developed for use in India and is adapted from "Ideas for Science Investigations" by Victor M. Showalter and Irwin L. Slesnick. It is a source book of ideas for student research projects. Three model projects are described, illustrating different approaches taken by three students to the investigation of the rise of sap in plants. These include realistic descriptions of searching for information, formulating the attack on the problems, maintaining records, and reporting results. In the next section, over 100 phenomena or situations are described, each with a series of questions suitable for experimental investigation. Most topics are arranged alphabetically with no attempt to classify them according to traditional science disciplines; many are interdisciplinary. References are given to sources of ideas, techniques and background information. (EB)





Research Ideas for SCIENCE PROJECTS

Based on *Ideas for Science Investigations* by Victor M. Showalter and Irwin L. Slesnick

K. C. GOYAL and PIYUSH SWAMI

Regional College of Education, Ajmer

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FOREWORD

For some years past, the National Council of Educational Research and Training, professional arm of the Union Ministry of Education, has regarded science education as a top priority and has worked progressively to prepare instructional materials and teaching units for science at the school level of education. At every point it has been conscious of the need to develop a scientific attitude of mind and an understanding of scientific method among Indian children and to impress upon them how important it is constantly to ask why things are as they are in their daily lives.

This excellent book of short scientific investigations, sometimes reported story-fashion with young Indian scientists for protagonists, is precisely the kind of thing we now need to show our children what they must do and think from day to day to develop the scientific outlook. This is the work of a team: K. C. Goyal and Piyush Swami of the Regional College of Education, Ajmer, I. L. Slesnick, USAID expert under the Ohio State University Program, and Billye Brown, who acted as the Chief Editor.

The range of the investigations included in this book should be an eye-opener to all of us engaged in education. They use scientific method to deal with the "why" of zoology, botany, physics, and chemistry and invade what was supposedly social studies territory to show how population problems are as "scientific" as sap rising in plants, the length of the life span among animals, cloud formation, the surface geography of the moon, vitamins, minerals, visual inversion, and a multitude of other things in our daily lives that we tend to overlook, so much do we take them for granted.

The approach throughout is through familiar things, in an easy conversational way that attracts children and that makes them see that the way of science is the way of daily common sense. For all children are curious to know *why*, provided the questioning way, which is the way of science, has been developed early as a matter of course in the home and the school.

Every section contains questions that the child must puzzle out for him/herself. It is for "Rekha" and "Khan" to work the answers out for themselves, with the assistance of teachers and materials provided. If the materials are not available, it is their business to make their own materials and to plan in time for the completion of their investigations.

In time is a phrase of the utmost importance for both children and adults engaged in the adventure of science teaching and learning, for—the authors seem to be saying—results are sure to come provided you plan for them with reason and good sense with the materials that you are able to evolve. Nothing except reason and good sense is necessary to the discovery of further knowledge.

The National Council of Educational Research and Training is delighted that a book of this kind has been written and made available to Indian school children. Sequels to it are invited as testimony to the usefulness of such material for both our children and our teachers.

L. S. CHANDRAKANT
Joint Director
NATIONAL COUNCIL OF EDUCATIONAL
RESEARCH AND TRAINING

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INTRODUCTION

The experience of doing a science project can provide a student with new knowledge and new skills as he works in the laboratory, workshop, field, or library. However the greatest good that comes from project work is the personal experience of pursuing scientific discovery. In an investigative type science project the student first becomes intrigued with a natural phenomenon. He then finds out all he can about the phenomenon by exploiting the available sources of information. When he reaches a "frontier" of knowledge, he asks an experimental question—a question that must be answered by an active search.

Research Ideas for Science Projects is a book that presents more than one hundred provocative phenomena to the reader. With each phenomenon several experimental questions are asked. Part I was written to illustrate in detail how a research project can be initiated and carried through. The phenomenon of sap rise in plants is developed in depth. The authors then relate how three school students, Rekha, Arun, and Khan, each developed a research project after having asked their own experimental questions about the phenomenon of sap rise.

In part II the phenomena cum experimental questions have been listed alphabetically according to title. Since phenomena are largely interdisciplinary by nature, no attempt has been made to sort them according to the traditional disciplines of physics, chemistry, biology, geology, and psychology. To aid those students who seek ideas for investigation in specialized fields, a subject index appears on pages 59-60.

Research Ideas for Science Projects is not a book of recipes or directions. The ideas presented are really examples of what the student himself must create. The science student must recognize that the truly creative person asks his own experimental questions of phenomena that he has personally encountered. Provision is made on page 56 for the reader to record phenomena and questions that he would like to pursue.

The authors believe that science project activities can be carried out profitably in the science club. Science club activities such as educational trips, preparation of charts and models, and the training in handicrafts such as soap making, may be more beneficial when the aims of the organization are to provide students with experiences in research. Some teachers and students may, however, find that individual scientific research can be related to the regular science course work. Home projects and special laboratory work can be undertaken by the gifted and advanced students.

This book is an adaptation of *Ideas for Science Projects* (1962), and its revision, *Ideas For Science Investigations* (1966), by Victor M. Showalter and Irwin L. Slesnick. These American editions were published by the National Science Teachers Association, Washington, D.C., U.S.A. The authors are grateful to the Association for permission to adapt the book to the Indian scene.

The authors wish to express their gratitude to the many individuals who became involved in the production of this book. Few of the ideas presented here are original, but it would be difficult to credit each source properly. Most especially, recognition is due Irwin L. Slesnick for his guidance as consultant to the production of the manuscript

Billye Walker Brown, who as chief editor purified the final draft and supervised the composition of this edition

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K. C. GOYAL and PIYUSH SWAMI
Regional College of Education, Ajmer

PART ONE

Using This Book:

to be read before beginning

I. To Students Using This Book

Investigation vs. Projects

Your own science study can be exciting as well as educational. To make it as exciting as possible, you will need to make your study an *investigation* rather than an ordinary *project*.

To most people, doing a science project means building a display to show how something works or to illustrate some well-known principle of science. A *research project* (an investigation), on the other hand, involves a search to understand the unknown, and begins with a question.

In doing the usual science project you report on, duplicate, or adapt something that someone else has discovered. In doing an investigation, you are the discoverer. This doesn't mean that doing an investigation will earn you world fame as a discoverer. It does mean that you can discover something, a fact or relationship, that was unknown to you and that was not recorded in any book available to you. Scientists refer to this as an *independent discovery*.

A good example of such an independent discovery is shown in a recent Nobel Prize in physics that was awarded to three different scientists who worked at three different universities and independently discovered the same relationships that are now the basis for quantum electrodynamics.

While your discovery may not merit a Nobel Prize, it may make a genuine contribution to mankind's knowledge. Your investigation will certainly give you a sample of the thrill of discovery.

What This Book Is

This book is a source of ideas for doing science investigations. Suggestions are made for questions to investigate, resources to use, and ways of doing the investigation.

Part Two, "Development of Investigations," shows three different investigations based on the same natural phenomenon—the rise of sap in plants. Each of the three students who did these investigations used a different approach. Each identified his own *crucial question* that was the very heart of his investigation.

The same sap-rise phenomenon could undoubtedly lead to more and yet different investigations. Twenty people with different backgrounds could probably ask twenty different questions that would be worth investigating. Some questions turned out to be better than others, but it is difficult to recognize these "good questions" at the beginning of a study. Consultation with your teacher is probably the best way to decide whether or not a certain question is suitable for your investigation.

Part Three, "Ideas for Investigations," is a collection of brief descriptions of phenomena or situations and questions that you might logically ask about them. Seeking answers to these questions, or others like them, would be a science investigation. If answers are found they should contribute to a general understanding of the phenomenon.

Part Four, "References," is a collection of book titles that may be useful in providing more ideas for or about science investigations. Some of these books you may find in the school library, the nearest college library, and other big libraries.

What This Book Is Not

The ideas in Part Three are not guaranteed to lead to successful investigations. To our knowledge, most of the specific questions have *not* been investigated by high school students. Therefore, there is no recipe or recommended procedure for investigating any one of the questions—doing that is up to you and your own creativity.

Nor are the questions following the

descriptions in Part Three the only worthwhile questions that could be asked. In fact, the best question for an investigation is one that the investigator himself or herself (that's you) asks or thinks up.

There is no guarantee that all the ideas expressed in this book are original. Certainly most of the phenomena described are known to many others. It's impossible to know, for sure, whether or not the same questions have been asked.

How To Use This Book

If you intend to use this book for its greatest benefit to you, do the following:

1. Read the description of the sap-rise phenomenon and try to picture the situations described.
2. Read each of the three case histories of good investigations based on the sap-rise phenomenon. As you read you will try to identify the various steps during investigation and the possible sources of help.
3. Read descriptions of the phenomena in Part Three. As you read, try to develop a mental picture of each phenomenon. Note that none of the phenomena is really limited to one science discipline (e.g. chemistry). *Be mentally alert to identify other phenomena that you know about and that may be related to those you read about.*
4. Read the questions relating to the phenomena and keep in mind that these questions are only examples. Your own question may be better. On the last page of Part III there is space for you to make a note of your own questions as you think of them.
5. If a certain phenomenon appeals to you, *find out more about it*. Some books listed in Part IV *may* be useful. The nearest library or your teacher can probably provide extra information. Take the help from your teachers and other resources wherever you feel it necessary.
6. Set up a plan of investigation. Some of the references will be helpful here, too.

II. Development of Investigations

Sap-Rise Phenomenon

When plants evolved from sea to land, one problem that had to be solved was the transportation of water from the soil to the aerial portions of the plants. Structurally, we see that a tube-like tissue called *xylem* developed which conducts the sap in an upward direction. Yet, many questions about how water rises from the roots to higher organs remain unanswered.

If man had been the architect of plants, a mechanical pump might have been the means by which water were moved from the roots to the upper parts of the plants. No such device, however, can be observed in a neem tree or in a petunia. If there is something in plants that acts like a pump, it must be composed of the plant cells themselves.

The "natural pump" in plants accomplishes some amazing results. A palm tree may be thirty metres high. During an average day this tree may evaporate as much as 600 litres of water from the leaves clustered near its top. Each day the pump in the tree lifts its water, some 600 kilograms, to a height equal to a seven-storey building, expending energy equivalent to carrying twenty litres of water (twenty kilograms) up seven flights of stairs thirty times each day.

The Eucalyptus, the Coast Redwood, and other trees grow taller than 90 metres. Their internal pumps must force water three times as high as the familiar coconut palm. One redwood is known to be taller than a twenty-five-storey building.

Can You Answer These?

Is the height to which a tree can grow limited?
Is there a limit to the heights to which "plant pumps" can force water?
How are plants, especially trees, capable of producing water flows that are more than just a trickle?
What part (or parts) of a plant is responsible for moving water?
What is the source of the energy that must be expended in lifting water?
How do plants pump sap?

These questions, and more like them, have been asked many times; many different answers have been proposed. Yet no one is certain that the right answer has been found to any of the questions. Consider the question, "How do plants pump sap?" This question is fundamental to the other questions. Many *hypotheses*, or possible explanations, have been made by professional and amateur scientists. A scientist bases his hypothesis upon the data available and his understanding of the problem. Sometimes few data are available, and the scientists' hypotheses are essentially "educated guesses."

One hypothesis to explain sap rise is based on the same principle that explains what causes liquids to rise in a piece of blotting paper when a corner is touched to the liquid. This phenomenon can be demonstrated in the laboratory by showing that water rises in glass tubes that have small diameters. The smaller the diameter of the tube, the higher the water rises. Technically, this is called *capillary action*. If you split the stem and root of a plant you will find some tube-like structures. Is capillary action the answer to the rise of water in plants? If it is, would the upper branches of dead plants or trees be moist or dry?

A second possible explanation of pumping describes a "cellular bucket brigade" with living cells forcing each drop of water up a series of steps. This hypothesis could be based on two facts: (1) living cells are known to be capable of converting chemical foods into energy, and (2) energy is required to lift anything upward against the force of gravity.

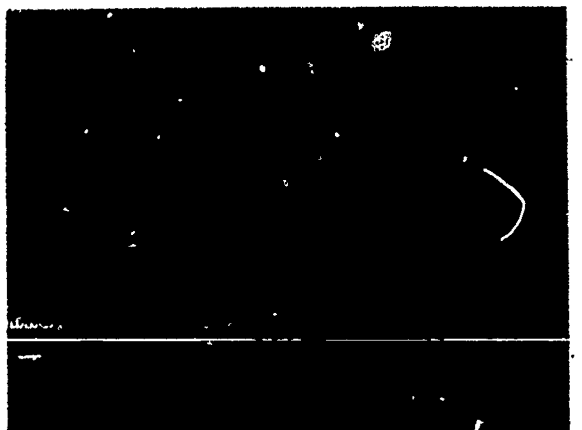
Is the living cell the key? If all the living cells in a band running around a tree trunk were cut away, the leaves would soon wilt, dry up, and die. This suggests that the living cells do serve as a continuous bucket brigade. But must the cell be living to transport sap? What would happen, for example, if all the cells in a tree trunk were killed but left in place?

The scientist Strasburger sawed off a twenty-one-metre oak tree close to the ground. He placed the bottom end of the trunk in a solution of picric acid, which kills cells on contact. The solution killed the cells as it moved up through the tree. Three days later, a tracer dye was added to the solution. The dye was later found at the top of the tree. Does this tell you anything about dead cells or related factors?

Are there sources of energy other than the living cell that might provide the necessary energy for transporting water upward? The concept of the energy of moving molecules is often used to explain the following "carrot-and-glass-tube" demonstration and provides a third possible explanation to our problem. A long glass tube is inserted into the top surface of a carrot and sealed in place. The carrot is placed in a beaker of water, and water slowly rises in the tube. The buildup of pressure within the carrot is referred to as *root pressure*. The diffusion of water through the carrot cell membranes is called *osmosis*.

When plants are cut off several inches from the ground, sap will flow up out of the cut surface. If root pressure causes the upward motion of water, is it possible for roots of the 90-metre Redwood to develop the 40,000 grams per square centimetre pressure required to raise water to its top branches?

A fourth idea that might provide an answer is the phenomenon of air pressure. Suppose an open-ended tube is upright in a container of water. If air in the tube is removed, the pressure of the outside air pushes the liquid up the tube. This same principle explains what makes a soda straw or a mechanical lift pump work. If air pressure forces liquids up in plants, how could the pressure be reduced inside the plant? If the inside



pressure were reduced, how could air pressure force the sap to rise?

Another possible explanation for sap pumping in plants may be found in the *cohesion* of water. Scientists have found that water molecules have an attraction for each other. If a long tube of water were subject to a pull at the top, each molecule would tend to lift up the molecule below it. Most of the water that leaves a plant escapes as vapour from leaves, and only a small amount, if any, evaporates from stems. Could the escaping water molecules be the pull required? A model of this has been built in the laboratory (see Figure 1). Evaporation occurs at the outer surface of the porous cup. If the water is absolutely free of dissolved air, the mercury may rise more than 200 cm. Remember that normal air pressure can force mercury up only about 76 cm.

If pull is developed, the water in a tube is under tension, i.e., it is being "stretched," and only the attraction between its molecules holds the water column together. If tension sometimes exists in the tube-like structures of a tree trunk, what would you predict would happen to the diameter of the trunk? Tree trunk diameters do undergo a cycle of shrinking and expansion every twenty-four hours. Is the "pull-cohesion" hypothesis the answer we have been looking for? If so, how does sap rise in trees in the spring when there are no leaves? What is the source of energy that moves the sap upward? How is the "pull-cohesion" hypothesis any different from that of capillarity?

Perhaps none of the hypotheses described considers fully all of the observed facts. Once we accept the fact that sap rises in a tree, we realize that there must be an explanation for the phenomenon. Considerable time, thought, and experimentation may be necessary, however, before the explanation is found. The rise of sap in plants is not a problem for the botanist alone. Physicists and chemists also may be involved in developing an explanation. Almost any common natural phenomenon can lead to research in a special field of science.

Regardless of background and interests, a high school student can begin with any natural phenomenon, like the rise of sap, and identify a specific project after a period of study and thought. The solution of the problem through intensive library, laboratory, and field research constitutes a science project. A project need not give the complete solution to a problem to be successful. Often the most successful project is one that suggests other research or contributes to the future solution of a problem.

In the following pages you will learn how three students started with the general topic of why and how sap rises in plants and how they developed worthwhile projects. When you do a science project, you will probably meet difficulties and pleasures similar to those encountered by Rehka, Arun, and Khan.

Rekha's Project

Origin of Project

Rekha was 16 years old and a class ten student of an urban school. She was interested in flowers and was fond of arranging them for decoration purposes. One day at school while she was preparing a bouquet of flowers for a classroom, the school mali observed her technique. He was bothered that she allowed the cut ends of the flowers to be exposed to the air before placing them in water. He advised her to cut the flower stems again while holding them under water before putting them in a vase. Flowers prepared in this way, he claimed, remain fresher longer than flowers cut in the garden and later placed in a vase. She followed his suggestion but was puzzled by the reason for doing so. The attempt to get an explanation from the mali of how an underwater cutting delayed wilting was fruitless—he just did not know the reason.

Rekha's knowledge of the phenomenon was sketchy. She knew that water deprivation caused wilting of flowers and that the water apparently flows up through the middle of the stem. Her teacher told her that the problem is related to the "ascent of sap" and "transpiration" phenomena, and then advised her to read some books on the topics.

Library Search

Rekha read all about the "ascent of sap" and "transpiration" from the available texts and reference books on biology and botany. She also read about the structure and functions of stems. One fact that appeared most significant from this study was that a continuous thread of water from the bottom of the stem to the top is a necessary condition for transpiration to continue. She reasoned that plants cut in the air and then placed in water would have developed air spaces in the xylem tubes which would slow the movement of water up the stem. Further reading informed her that the rate of transpiration is also influenced by the temperature, moisture in the air, the kind of plant, time of day, and season. Rekha, on the advice of her teacher, read about *potometers* which are instruments for measuring the rates of transpiration.

Specification of the Problem

Rekha now *hypothesised* (developed a tentative explanation) that the cut flowers that are placed in water immediately after cutting remain fresh for long periods. On the other hand, the flowers that are exposed to the air for a long time before being placed in water wilt earlier than the flowers treated in the first way. She thought that the duration of time of the exposure to air before placing flowers in water determines their period of freshness. The reason for this, she gave, was that air spaces block the xylem tube and discontinue the water strand, thereby hindering the pull of water up the stem. Rekha decided to test this hypothesis in two ways. Therefore her specific problem was: "Is the rate of water flow through the stems of plants significantly influenced by the air exposure of the cut ends of stems?"

Design of Experiment

Rekha thought it better to consult again with her teacher who then advised her to proceed with the projec . First of all the teacher advised Rekha to take for experiments those plants that show good rates of transpiration. The teacher inspired Rekha to take the initiative and search for such plants herself. Rekha collected from the school garden a sample of stems having leaves and flowers. She put these cuttings into separate beakers with small but equal amounts of water. These beakers were then put in the sunlight. The kind of plant that showed the earliest wilting was chosen by her for the experiment. In all, she devoted one week to consulting with the teacher and searching for and selecting the plants for the experiments.

Then she thought of getting a potometer. She did not have sufficient money to purchase one, so she tried to borrow one from the school laboratory. However, the teacher did not wish to risk having the potometer broken by Rekha and therefore would not lend it to her. Rekha decided to build one and allotted one week's time for the construction of her own potometer. She then allotted two full weeks' time for doing experiments and recording observations. An additional two weeks would be needed for the interpretation of data and the preparation of her paper and exhibit. Altogether she estimated that this phase of her project would take six weeks. Here it should be noted that the school science club also offered her the opportunity to work with it; but because of the small space at the disposal of the science club for working she chose to work in the school laboratory.

Difficulties in Getting Started

Rekha planned her project enthusiastically. The idea of working on a problem herself fascinated her completely. But her laboratory skills were not well developed. Therefore construction on the potometer was started only after learning such skills as glass fabrication and operation of a high-temperature torch from her teacher. After constructing the potometer she learned the technique of taking the reading with the potometer. Now she was ready to start the experiment.

Maintaining the Records

Before Rekha began to measure the rate at which water flowed through the stems of the flowers she had selected for testing, she prepared a form on which many of her expected observations could be recorded. She included spaces for noting the name of the plant she was using, the type of treatment it was receiving, the date, potometer readings at the beginning and end of observation, the time interval, the time of day, temperature, humidity, air pressure, and light intensity. Some space was reserved for observations which she could not

While collecting data, Rekha gives her undivided attention to the potometer and the timer. Readings and observations are recorded immediately.

anticipate. When she completed the sequence of tests, she had a neat and convenient record of the data in her observation notebook. Rekha found that the measurements during the first two days of testing were easily remembered. But the mass of information collected by the end of even the first week was easily confused whenever she discussed her progress without referring to her notes. She further found that the writing of the final report was greatly facilitated by the full and accurate records she had maintained.

Keeping on the Track

Rekha recorded the water flow rates three times a day except on Sundays and holidays, when she took potometer readings hourly. She took the first reading at the time school started each day, the second reading during her lunch period, and the third reading after school closed. For every reading, she would cut one plant while holding it under water and immediately fit it into the potometer. Then she would fit into it another plant whose stem had been cut earlier and exposed to air for some time. After a few days of work she noted that the plants that were cut in water had a more rapid rate of transpiration than the plants treated otherwise.

Incidentally, she also found that the rates of transpiration in plants cut both ways varied with respect to the time of day. She was curious to confirm this finding by doing experiments with other kinds of plants. But Rekha at present stuck to her specific problem, i.e., the effect on the rates of water flow up the stems of plants when their cut ends were and were not exposed to air. She decided to confirm her observations of the effect of time of day on the rate of water flow in the stems after she completed her original project.

Reporting the Results

After she noted all the potometer readings over a period of two weeks, the important work before her was to use these data to answer her original question and to prepare a project report.

Rekha calculated the difference in rates of transpiration for the plants treated both ways at different times of day. Similarly, she also noted the differing rates of transpiration in plants treated both ways at different temperatures over many days. With these two findings she was able to state more strongly in her final report that the plants that are cut while held under water show a more rapid rate of transpiration when compared with plants that are cut in the air. This was true not only at the same time and at the same temperature of day but also at various temperatures and at various times of day.

Rekha was asked by her science teacher to present her findings before the class. She decided to prepare a full report of her project for this occasion. Her report was based on the following outline:

Title

1. Summary
   A. The topic or problem investigated.
   B. The explanation of the problem.
   C. The most important information gained from the investigation.
2. Discussions
   A. Circumstances leading up to project.
   B. Acknowledgment of help received from other people.
   C. Methods used in investigations.
   D. Tabulation of findings.
   E. Conclusion and reasoning upon which it is based.
   F. Arguments for the suggestions to other workers.
3. Appended Materials
   A. Drawings, photographs, graphs, and calculations supporting the project report.

After her first appearance before the class, Rekha was invited by the school science club sponsor to present her findings before the members of the club and some other invitees. Upon recommendation of her teacher, the science teachers of neighbouring schools also invited her to give full details of her project. And lastly, her project was put on exhibit for the science exhibition and science fair held in her locality. The preparation of a formal report of the project helped Rekha to present her arguments pointedly and correctly.

Further Experimentation

Rekha was pleased that her project had worked out so well and had enabled her to receive recognition from her school and neighbouring areas. Yet, she was surprised that the work had raised far more questions than it had answered. Her reading on specific topics in plant physiology increased. Now she wanted to work on such problems as:

1. Do the rates of transpiration also vary in other plants with the change in time of day?
2. Does the transpiration rate in cut flowers have a definite period?
3. What is the best temperature at which to keep cut flowers fresh longest?
4. What are the quantitative relationships of transpiration rates to humidity, temperature, and light?

Rekha now had many questions to answer. With the proper guidance of her teacher she got pamphlets and books from the Central Ministry of Food and from the libraries situated in the vicinity. She also wrote to the nearest Block Development Officer to send her literature on the topics mentioned by her. She had already started work on these new problems.

Arun's Project

Origin of Project

Arun, a class ten student in a higher secondary school, had shown a high mechanical aptitude since early childhood. He spent hour upon hour with his mechanic friend at a garage and had learned how automobiles and engines work.

Arun heard about sap-rise phenomenon in a science class, when his teacher demonstrated root pressure by using the carrot and glass-tube device. The results were not impressive. The water did not actually rise. On the next day Arun found that the water in the tube had risen a little. He wondered what caused it. A series of questions came to his mind. Among them were:

1. Why did the water rise?
2. Is it possible to measure small changes in pressure? If so, with what device?

These problems interested him, and he made up his mind to attempt to investigate them.

Search for the Goal

Arun was very serious these days. He was not interested in his co-curricular activities; he was always found reading books. One day his teacher asked, "What has happened to you, Arun?" Arun told the teacher about his problem. The teacher suggested that he consult physics books, and he offered Arun several of his personal books to take to his home. Arun accepted the offer. While he was on the way home, Arun thought his mechanic friend at the garage might help. This friend showed him the working parts of a pressure gauge (a device for measuring pressure). To Arun it looked complicated and he wondered about its construction, but the mechanic could not make Arun understand how the device worked.

After going through the physics books, Arun began to understand the concept of pressure and the terms associated with it. On the advice of his elder brother, Arun looked for some more books about scientific instruments. From these books he learned that *manometers* and *barometers* are common devices for measuring pressure. He also gained some knowledge of *osmometers,* which measure osmotic pressure.

Specification of the Problem

After learning about the osmometer, Arun made a list of the equipment that would be required for the construction of an osmometer. He asked his science teacher to lend him the needed equipment, but the teacher refused. He told Arun that he would have to define the problem specifically before he could get the equipment. Arun was disturbed at this, as it was difficult for him to define or express exactly what he wanted to do. The next morning, after a great amount of thought, he prepared a note and consulted his English teacher, Miss Neelu, who helped him to prepare the statement.

Arun was very happy and excited when his project proposal was accepted by his teacher. The statement Arun had prepared was, "How can small root pressure changes be measured accurately and quickly?" Arun was congratulated by his teacher who then released the equipment that Arun required.

Arun thought it would be easy to organize his work if it were divided into phases. The divisions were:

1. Design of device
2. Construction of device
3. Measurement of pressures

On the advice of his teacher Arun assigned a specific time to each phase of his project. He proposed seven weeks to complete the project, assigning two weeks to each phase and one to unexpected happenings.

Difficulties in Getting Started

Arun constructed several pressure-measuring devices that he had read about in the books, but none of them gave satisfactory results.

Later on he decided to work with a manometer. He bent a capillary tube making it into a U-shape. He found it difficult to fill the tube with mercury, however, because of the air bubble that formed inside the capillary tube. He was able to overcome the problem of removing the air bubble only after many trials. This took him one complete day.

The next problem was how to measure precisely the rise of mercury in the tube. He selected a metre scale and placed it behind one end of the capillary tube. He found the metre scale could not be used to measure the small rise in the level, as the smallest distance that the metre scale could measure was only 0.1 cm. Arun tried his best to solve this problem of measurement, which took another day.

The following day he observed his elder brother plot a graph between pressure and temperature. Arun examined it minutely and asked his brother to explain the graph in detail. His brother told him that with the help of this graph, pressure can be determined at any temperature. This gave Arun an idea. He asked the brother whether the graph could be used as a scale. The reply was yes. Arun took similar graph paper and compared it with the metre scale. He found that the graduations were nearly the same as those of the metre scale. Arun decided that his purpose would be served better if he divided each division of the graph in two equal parts. This paper attached to the side of the capillary tube helped him measure any small changes.

Maintaining Records

Arun began to construct his device according to his plan (Figure 2). He kept a record of his progress and other ideas that occurred to him. When the device was completed he planned to record the performances and data for measurement of root pressure.

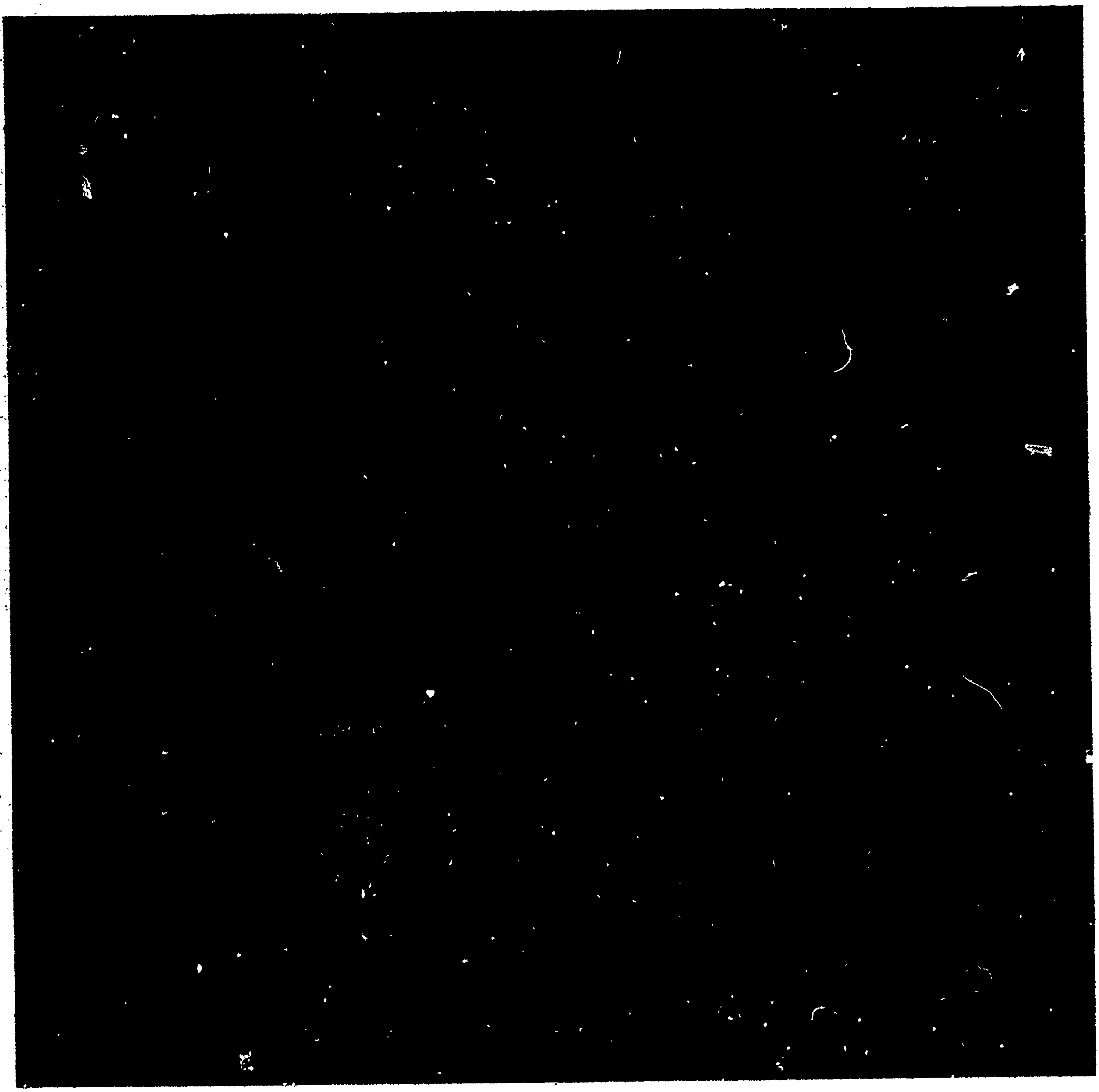
By now Arun had constructed his apparatus to measure the small root pressure changes. He measured the root pressure in a potted plant that had been well watered. The stem was cut off a few centimetres above the soil level and the stump was connected to one end of the manometer by means of rubber tubing. Arun observed the rise of the level of mercury in the free limb of the manometer and recorded the amount of rise.

Reporting Results

Arun found the results to be quite satisfactory, i.e., the root pressure that he measured was of the order of 1.5 atmospheres. He decided to display his work in the science exhibition to be held in the town. He explained each phase of the apparatus in detail as he thought most people at the exhibition would wonder what it was and how it worked.

Further Encouragement

Arun was congratulated by his teacher, friends, and parents when he was awarded a prize in the exhibition. His brother pointed out that he was fortunate to have had help from several sources, especially his science teacher. Arun realized that he had received considerable help from his friends, teachers, and the authors of the books he had read. He felt encouraged to undertake further projects.



Khan's Project

Most scientists enjoy discussing their specialities with students who are eager to learn.

Origin of Investigation

Khan had the reputation of being a brilliant boy, as he stood at the head of his class in science subjects. One day a fellow student asked him why water moves upward in trees. He answered his fellow student by saying that he did not know but would have the answer the next day. Khan had seen an article on sap-rise phenomenon in the newspaper, but the explanation of how sap rises was not clear to him.

Khan then read in some of the text-books on plant physiology which gave the usual possibilities but none satisfied him. The next morning Khan gave the accepted pull-cohesion explanation to his friend. Khan had some personal reservations about the theory but after all, he did have a reputation for knowing all the answers.

That evening Khan went to the library and read further in the plant physiology text and then looked for books on physical chemistry for more information about *osmosis* and *capillarity*. He came across a description of *electro-osmosis* almost by accident. In this phenomenon liquids move through small tubes when an electrical potential difference is applied across the tube.

He read further and found that when liquids are forced through small tubes a difference in electrical potential is established across the tube. This phenomenon is called *streaming potential*. At the time Khan did not quite realize that he was beginning a research project. Both of these effects, electro-osmosis and streaming potential, were bound to be very useful for his research.

Within a few days, Khan was very excited about the rise of sap in plants. No textbook gave a satisfactory answer. Many physical effects were known, but no one was sure of their relationships. Here was a challenge to explore the unknown. From previous projects, Khan knew the experimental investigation of questions which did not have ready-made answers was enjoyable and rewarding. The rise of sap in plants was such a common, and yet important, phenomenon that it deserved a better explanation than he had been able to find. He had to investigate the rise of sap in plants.

Literature Search

Reading to gain information was easy for Khan. He read other textbooks on plant physiology and physical chemistry. He checked some of the science journals. The topics he looked under were ascent of sap, osmosis, electro-osmosis, streaming potential, capillarity, and water transport in plants.

In searching for further sources of information he consulted a professor of botany who was a neighbour and a good friend of his father. The professor referred Khan to a specialist in biophysical chemistry in the university. Khan consulted the specialist.

Establishing a Hypothesis

After the meeting with the specialist Khan returned home. In the evening, when Khan had just started his homework, a new idea to explain the ascent of sap in trees came to him. It took him nearly half an hour to get the new idea written down, and another ten minutes to give a suitable title to his explanation: "The Autoelectro-osmosis Hypothesis." Khan's hypothesis read as follows:

"Assume a small vertical tube in a tree—a tracheid. Assume the tracheid is filled with water. Water diffuses outward through the tracheid walls. The diffusion produces an electrical potential difference between the inside and outside of the tube-wall (streaming potential). Suppose the diffusion is more rapid at the top of the tube, the potential difference will be greater at the top. If this is true, a potential difference will exist between the inside top and the inside bottom of the tube. From the known phenomenon of electro-osmosis, an upward liquid flow will be initiated in the tube by this potential difference."

Khan's hypothesis was liked and appreciated very much by his teachers and the specialist. Khan was surprised at the specialist's curiosity and interest in the same problem.

In discussing the hypothesis, Khan realized that the scope involved was greater than he could hope to investigate in one school year. The specialist pointed out that there were several specific problems that could lead to a final and conclusive test of the hypothesis. These smaller parts could be investigated with the time and facilities available to Khan.

The specific problems agreed on were:

1. How is the electro-osmotic flow rate affected by the magnitude of the potential difference?

2. How is the streaming potential affected by the rate of osmosis?

3. How are streaming potential and the electro-osmotic flow rate affected by the nature of the membrane through which the flow occurs?

Both agreed that each question would be answered quantitatively. Before Khan completed his discussion with the science specialist, they designed an apparatus that could be used for the investigations (Figure 3).

Systematic Attack

Khan realized that a great deal of work had to be done. He did not think it was practical to set a time schedule, but he made an outline to show the order in which things would need to be done skillfully. He listed the different stages of the problems as follows:

1. Construct apparatus.
2. Find appropriate solutions and diaphragm.
3. Record flow data when all conditions except voltage are constant.
4. Record voltage when all conditions are held constant except flow rate.
5. Repeat the observations with different diaphragms and different solutions.
6. Write a summary of the findings.

Khan thought that in addition to his general problem it would be worth while to extend his readings to search for information on electrical potentials known to exist in plants.

Maintaining Records

Khan now had a promising problem for investigation, a strong reading background, the personal advice of a professional scientist, and a sound plan of attack. He was ready and eager to start work—but he did not. First, as president of his school parliament and secretary of the science club, he became involved in helping to plan school social activities, such as a parent-teachers association meeting to help community developments. In addition, it seemed as though all his teachers were "piling on" the homework, and Khan was also taking tutorial classes after school hours. His work seemed to be never ending. Since Khan was a good player of school games, the head master and the games in-charge decided that he should participate in the State Tournament. So he was asked to practise for an extra half hour each day.

Thus it became difficult for Khan to find time for working on his project. The weeks flew past but at last he began to work.

Experience had taught Khan the value of recording every observation. With the pressure of time-demanding activities, he felt a thorough record was even more necessary, since there were stretches of ten or more days when he could not spare time to work on the investigation. Khan's system of keeping records consisted of three phases:

1. To maintain daily progress.
2. To keep a card index of the books and articles he read along with summaries of the relevant facts.
3. To set up tabular forms to record specific experiment results.

Keeping on the Track

As Khan's work progressed, many interesting side questions arose, such as:

1. How fast does sap flow in plants and in individual tracheids?
2. What do biologists know about the movement of liquids in and out of cells?

These questions did not distract Khan.

The central membrane (M) and metal gasket assembly (A) joins two glass tubes (B) with the test membrane (M) between the tubes. Three C-clamps (G) at 120 degree separation are used. Electrical contact with the solutions on opposite sides of the membrane is made through connections (C) and the metal halves of the gasket assembly. Electrical contact between the metal halves is prevented by insulating gaskets.

Each glass tube has two access tubes (D) with stopcocks. These access tubes facilitate filling the glass tubes with liquids, permit escape of trapped air from the glass tubes, and allow manometers or other pressure gauges to be attached.

The electric circuitry has a voltmeter (V) and a battery potentiometer (E). The battery may be disconnected by means of key (K).

He kept records of all interesting questions that came as his work progressed, so that he could look into them after this part of his investigation was finished.

Khan had many short informal talks and discussions with his science teacher. These helped to assure him that he was concentrating on the proper aspects of his project.

The specialist in biophysical chemistry also came to the school to talk to the science club. After the club meeting, he met with Khan and was delighted to learn of Khan's progress. The specialist encouraged Khan to keep up the good work and suggested that photographs of the experimental apparatus be included with the experimental data.

Reporting Results

Khan's work was completed just before the summer vacation. He made use of the extra time to analyse his results and to think about their implications. He found that the results were closely consistent with his original idea about "the autoelectro-osmosis hypothesis." The only big question in his mind was whether or not the membranes used in the experiment were enough like living plant membranes to give good results.

Khan then set down his hypothesis and preliminary investigations. He did this for two reasons. First, this is the way scientists communicate. Second, Khan felt that writing his ideas and observations in a logical order would clarify them in his own thinking and form a sound basis for further work.

After the completion of the report of his work, several copies were made and sent to the science specialist who helped him in his work, the school science library, the zonal director of science fairs, and one was kept for his personal records.

Value of Outside Help

At the school prize-giving assembly, Khan was asked to deliver a talk on his new work. He gave much of the credit for his success to the aid he had received from several sources. In his well organized presentation, he classified the ways he had been helped into four categories. They were:

1. Knowledge had been supplemented by reading.
2. Experimental techniques had been developed.
3. Assumptions had been confirmed.
4. The feasibility of his project had been assured.

Aging and Life Span

As organisms become old, they appear to lose their vigour and die. The maximum length of time an organism lives, its life span, is one of the characteristics that varies from species to species. The life span of man is approximately 115 years. The toad has a life span of 35 years, while the rat lives only 4½ years.

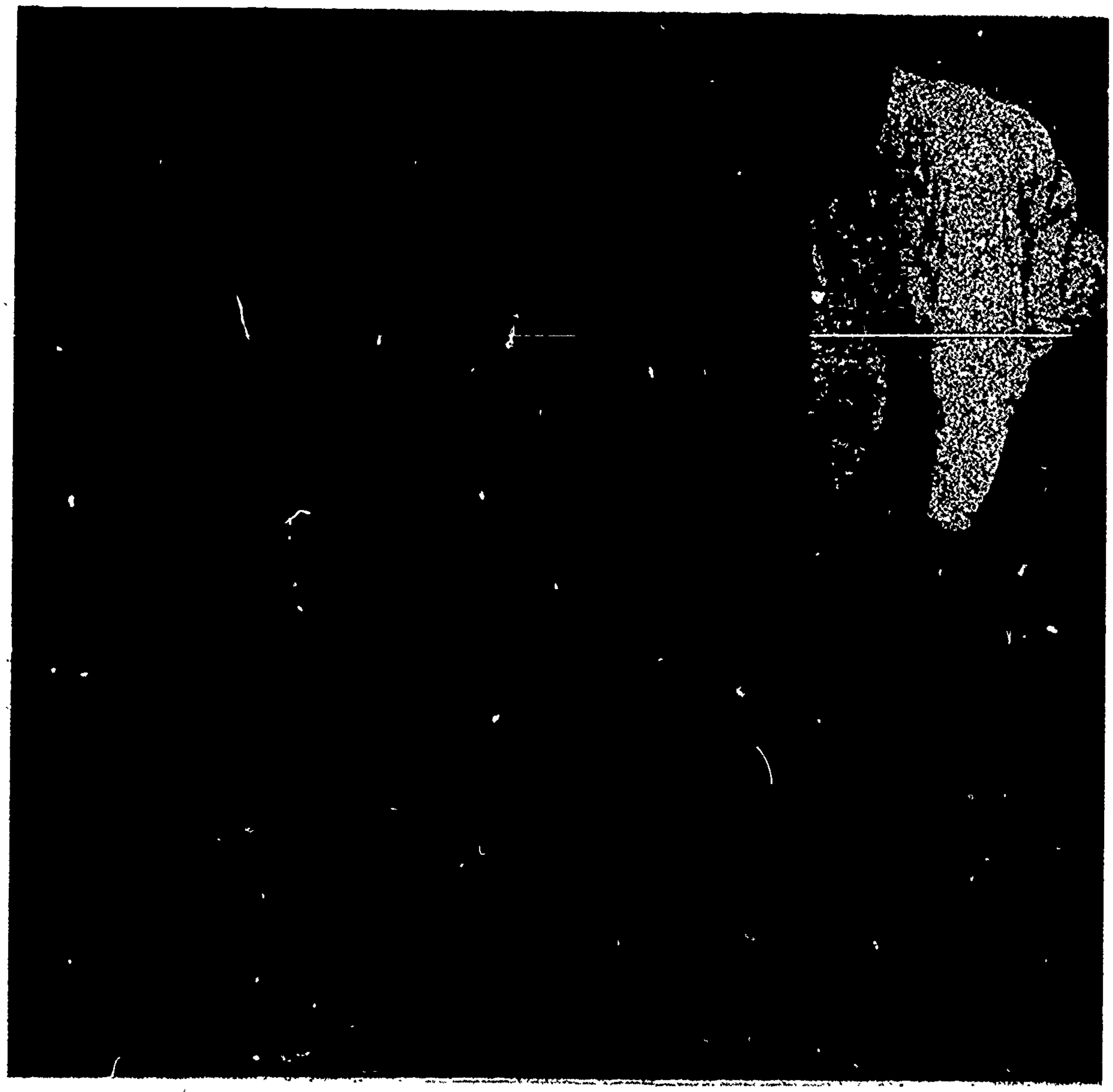
Aging is a complex process with many factors contributing to the causes. Man's life expectancy (average length of life) varies from one part of the world to another. Wild birds in the field live a considerably shorter time than the same species of bird kept in captivity. Here a contributing factor appears to be the hardship of environment. However, under carefully controlled laboratory conditions, planaria (a kind of worm) that are alternately starved and fed survive longer than those that are steadily fed. The regularity of intervals between feedings may be a controlling factor but other factors such as the quality of food, manner of feeding, temperature of the atmosphere, cannot be ignored. In order to test the effect of one of these variables, an investigator has to control all other variables.

Animals such as earthworms, pigeons, hens, turtles, and insects such as cockroaches and butterflies may be used by students in their experiments. The study of aging and life span in the case of man is limited to such things as surveys of family history and the examination of individuals for physical characteristics of the aging process.

In testing factors that control or influence the life span of an organism, it is better to study specimens having short life cycles. Fruit flies and water fleas are better subjects than turtles and pigeons. Consider the following problems for investigation:

1. What effects do the alterations in

diet, temperature of body, light, environment, or climate have on the life span of an organism?
2. Do the offspring of younger parents tend to live longer than the offspring of older parents?
3. Is the life span of one sex greater than that of the other sex?
4. Does the size of an organism affect its life span?
5. Does the old age of an organism affect its mental efficiency? Is there any truth in the phrase with reference to man and other organisms that "you cannot teach an old dog new tricks"?
6. What physical changes occur as organisms become older? What physical changes occur in organisms after death?
7. Do long-lived parents produce long-lived progeny? What is the genetics of longevity? Are there physical characteristics of a given organism such as the annual rings of a tree and the weight of lenses in the eyes of a rabbit that enable one to determine its age?


What changes in temperature occur within the jar throughout the cycle of cloud formation?

Animal Banding and Marking

Bird banding is an important activity among those who study birds. Information concerning migration, dispersal, and the life span of wild birds is only useful if gathered over a period of a number of years. The identification mark of the bird is tied or stuck on its leg or on its back. One method of using this technique has been given in the Butterflies section. Similarly, bats, rabbits, deer, fish, and even invertebrates are often marked for purposes of gathering data. You could use this technique to try to discover:
1. Whether land turtles, released miles from their water holes, will return to their water holes;
2. The number of years that frogs will survive in the wild;
3. Whether ants of the same species are acceptable and adaptable in nests of other queen mothers;
4. Whether honey bees follow the same route every day while going for nectar;
5. How far a sparrow will range from its nest. (Set out live traps at increasingly greater distances from its nest);
6. Whether cockroaches survive the winter and return to the same area the following year;
7. Whether honey bees come to the same comb after collecting the nectar;
8. Whether night beetles visit the same area every night;
9. Whether a bird returns to the same area each spring.

Animal Learning

The ability of certain animals to learn to run through mazes has often been demonstrated. Follow-up questions a researcher might ask are:
1. What senses do animals use in learning a maze? Does a mouse learn to smell, hear, or feel his way through a maze?
2. After an animal is able to learn one kind of maze, can it learn other kinds of mazes faster?
3. What effects do factors such as noise, strong magnetic field, infrared light, slope of maze, wind, distracting aromas, and vibration have on the learning of a maze or the recall of learning?
4. Do young animals learn mazes faster than older animals? Do young animals forget learning faster than older animals?
5. Is the use of food (reward) or electric shock (punishment) a better procedure for teaching animals to learn a maze?
6. A large population of fish maintained in an aquarium may be separated by a clear glass partition. How much time is required for the fish on each side of the partition to learn of its presence and cease bumping into it.

Artificial Clouds

You might be one of those persons who is fascinated with the phenomenon of cloud formation—the different kinds, when they will release rain, how much, and for how long.

If you are an experimenter you may know the difficulties in doing laboratory experiments in weather science. But did you know that clouds can be produced and experimented upon in a laboratory?

Take a five-gallon jug made of clear glass and introduce a little bit of water and a puff of smoke into the jug. Place an air-tight cork on the mouth of the jug. The cork should have a hole for passing a delivery tube which is connected to a cycle pump. Next, pump air into the jug. Does anything seem to be happening? The air inside the jug may be like the atmosphere at sea level when the air is being compressed and heated adiabatically. After pumping approximately twenty strokes release the pressure suddenly by removing the cork. The air will expand and a five-gallon dark-grey rain cloud will form inside the jug. Replace the cork and again pump until the cloud disappears.

1. At what temperature does the cloud formation take place?
2. How do the temperature, pressure, and humidity inside the jug change during the cycle of operation?
3. If the washer of the pump is reversed, does cloud formation take place? What will be the magnitude of the pressure?
4. Describe the relationship between the pressure and temperature during the cycle of operation.
5. How far should we cool the air in a room in order to form a cloud?
6. How much water is there in one cubic foot of cloud?
7. How much force is needed to hold the piston of the pump during the cycle of operation? Is the pressure within the system a function of the force exerted by the pump handle?
8. Just before releasing the pressure, how much work is done by the piston when allowed to move freely?
9. How does the temperature inside the cylinder of the pump compare with the temparature of the jug during the cycle of operation?

Barkhausen Effect

One end of a long soft iron rod is inserted (as a core) into a current-conducting coil. As direct current is increased steadily, the magnetism of the rod is observed to increase in finite jumps (Barkhausen Effect).

1. How do changes in temperature influence the Barkhausen Effect?
2. Could a glass tube packed with iron filings be substituted for the soft iron rod with the same results?
3. Does the steady decrease of the energizing current result in a similar decrease in magnetism?
4. What would happen if the soft iron rod were replaced by a steel one?

Behaviour Patterns

Many organisms show different kinds of behaviour in response to the same stimulus. Take for example the defensive behaviours of animals. In response to a threat, a dog may growl, snarl, and attack; a goat may silently run away; a bird may noisily fly away or vomit on the tormentor (as vultures sometimes do); a millipede may roll up into a tight ball; and the opossum may feign death.

Plants, though devoid of nervous systems, show definite movements and curvatures of their parts when stimulated with light, gravitational or centrifugal forces, and moisture. Similar simple behaviours of animals can be illustrated by the orientation of fish in a water current, the tendency of a mouse to run along a wall, and the attraction of insects and protozoa to or away from light.

Some animal behaviour patterns are very complex, as illustrated in the migration of birds and the integrated social structure of bees, ants, and termites. The scientific study of human behaviour patterns is the discipline called *psychology*.

Studies have shown that the behaviour of an organism is not random but directed and with purpose.

1. Web-building spiders produce an observable and preservable pattern of behaviour.
   a. How does the web pattern of an individual spider vary with such factors as age, hunger, thirst, and repeated sabotage?
   b. Do all members of the same species of spider produce identical webs?
   c. Can a spider finish the partially completed web of another spider?
2. Behaviour patterns of plants *(tropisms)* may be stimulated by light *(phototropism)*, earth's gravity *(geotropism)*, touch *(thigmotropism)*, and other environmental stimuli.
   a. Can the roots of a plant be made to grow towards light?
   b. What would be the behaviour of roots and shoots in a strong electric field?
   c. Tendrils are climbing structures that support the main plant. What would be the result if the tendril were touched with a part of the same plant?
3. What would be the behaviour of protozoa if they were placed in an electric field?
4. Migration of birds is due to their maladjustment with the environment of a place. What would be the effect on the normal behaviour of the birds in a box if the temperature and duration of light were varied artificially?
5. How long would a bird take care of artificial eggs that replaced her own eggs in her nest?
6. The reproductive cycle and mating behaviour of lizards can be controlled in an "environment box" where temperature, light, and humidity are controlled.
   a. Under what conditions of temperature, light, and humidity can lizards become reproductively active?
   b. What change in the gonads can be observed and measured throughout the reproductive cycle?
   c. Can the reproductive cycles of other animals be controlled in an "environment box"?

Biological Growth

A crystal grows by the addition of

molecules of one kind. A city grows when the population increases, when more houses are erected, or when more land is added and the boundaries of the city are extended. Organisms grow differently—in a way more complex than the mere addition of parts. An organism manufactures its own parts from the stuff in its environment. A seedling of a mango tree will change transparent gases (carbon dioxide and nitrogen), water, and several handfuls of minerals into a massive, colourful tree. Mice, through the processes of growth, change a diet of wheat, fruit, or meat into more hair, bone, and other tissues.

There are a number of aspects of growth that can be investigated.

Control of Growth

1. In what way do the hormones of the thyroid and pituitary glands affect the growth of animals?
2. How do auxins affect the growth of plants?
3. What are the effects of dietary changes (quantity of food, balance of nutrients, interval for feeding) on the growth of animals?
4. In what ways does the availability of light, water, and minerals influence the growth of plants?
5. How are the Japanese able to cause the stunting of trees so that fully mature trees can be maintained in small pots?

Rate of Growth

1. What are the effects of the daily duration of light and darkness on the rate of growth of bean seedlings?
2. How does top pruning or side pruning affect the rate and pattern of growth of plants?
3. What are the ratios between the growth of the length and the diameter of different plants?
4. If one were to plot the growth of an animal as measured in weight or height, against time, what sorts of curves would be produced? Do the growth curves of all mammals appear similar? Do animals grow in spurts? Or do they grow in a steadily rising curve that suddenly plateaus at adulthood?

How is the bouncing percentage of a ball influenced by the height from which it falls?

Bouncing Balls

A bouncing ball is a very common sight in our society. Balls can vary considerably in size, shape, constituent materials, density, and weight. The physics of a bouncing ball includes the interplay between kinetic and potential energy, the transformation of energy, and the elasticities of the ball and the reflecting surface.

The ratio between the height from which the ball is dropped and the height to which the ball returns can be expressed as a *bouncing percentage*.

1. What is the relationship between the angle of incidence and the angle of reflection of a bouncing ball?
2. Can the deformation of the ball and the reflecting surface be measured?
3. How is the resilience of an air-filled ball altered when the gas is replaced with CO_2 or propane?
4. Can the rise of temperature of the ball and that of the reflecting surface be measured?
5. Is there a mathematical relationship

among the bouncing percentages observed when steel balls bounce on solid steel surfaces, rubber balls bounce on solid rubber surfaces, and wooden balls bounce on solid wooden surfaces?

Buoyancy

The familiar lifting effect of a fluid upon a body that is either wholly or partly submerged in it is known as *buoyancy*. This phenomenon was studied first by Archimedes, a Greek philosopher who stated that buoyant force is equal to the weight of the fluid that the submerged body displaces. This force may be treated as a single force acting vertically upward through the centre of gravity of the displaced fluid. This is known as *Archimedes' Principle* and holds true whether the submersion of the body is partial or complete.

Archimedes' Principle is used to compute the specific gravity of substances, the diameter of very thin wire, and the diameter of capillary tubing.

1. What are the specific gravities of humans, dogs, and different kinds of fish?
2. How do specific gravities of the rocks in a region compare?
3. Do all kinds of concrete, steel, copper coins, and talcum powder have the same specific gravity?
4. How do the specific gravities of different kinds of paper (newspaper, blotting paper, writing pad) compare?
5. How do the bore of centigrade, clinical, and Reumer thermometers compare?
6. Does Archimedes' Principle apply to bodies falling into liquids? Does this law hold true in a stream of water?
7. A solid is fastened to a string and allowed to fall into liquids of various densities. How is the density of the liquid related to the acceleration of the falling body?
8. In the above experiment, is the acceleration of a falling body the same in two different liquids of the same density?
9. Can you show whether or not Archimedes' Principle of buoyancy holds true for gases as well as liquids?

Butterflies

Butterflies are of special interest to human beings. They are important to entomologists for collection and classification purposes. They are also used for basic studies, such as how butterflies communicate and the effect of hormones on their development. Children get amusement from catching them. A poet is inspired by the butterfly for writing new poems. Botanists and agriculturists are concerned with butterflies because of the damage their larvae (caterpillars) inflict on plants.

1. Are butterflies attracted to flowers by scent or colour?
2. Can it be said that one butterfly visits only one species of flower?
3. Is there any definite interval of time or pattern by which butterflies visit flowers?
4. How high can a butterfly fly?
5. Does the butterfly return to a flower from which it has already sucked nectar? Will butterflies visit a flower from which the nectar has been sucked artificially?
6. How long can a butterfly survive? What would be the effect of different temperatures and foods on their longevity?
7. What is the range a butterfly can migrate? (The wings of a butterfly can be tagged with a piece of self-adhesive, good quality paper that is $\frac{1}{2} \times \frac{1}{2}$ inch in size. More information regarding tagging can be had from Dr. Fred A. Urguhart, Zoology Department, University of Toronto, Toronto, Canada.)
8. Study of life history:
   a. How much time is required for each stage in the life cycle of a butterfly, i.e., from egg to adult?
   b. What is the determining factor of the time taken in development to adulthood—temperature, light, food, or anything else?
   c. How long can a chrysalis remain dormant?
   d. What changes occur from the chrysalis stage to the full adult? Observe it by peeling a different chrysalis each day and drawing sketches of the developing structures.
9. What is the nature of the colouring matter on the wings of butterflies—pigment or prismatic type?

Calcium Carbonate

Calcium carbonate ($CaCO_3$) is a common compound found in rocks of sedimentary origin. Limestone, marble, and chalk are largely $CaCO_3$, and shales and dolomites are often rich with this substance. Since ground water contains carbonic acid, (geologically speaking) the carbonate rock formations are readily weathered by dissolution which frequently produces caves. While $CaCO_3$ is being removed from the land, it is being deposited in the ocean by many organisms that use the compound in building skeletons.

1. Effervescence is a qualitative test in which acid is used to identify carbonate rock. If a gas is given off when acid is added, the substance tested may be carbonate. Under what conditions and to what extent can calcium carbonate be dissolved in acids? Do salts containing calcium ions, and salts not containing calcium ions, influence this solubility? Does an anion (a negative ion) have an effect?
2. Why does blackboard chalk of constant length generally break into the same number of pieces when it is dropped? Why does it break in a spiral when twisted? Why does chalk often squeak when used on a blackboard? How does natural chalk compare with manufactured chalk in density, adhesion to slate, fossil content, and porosity?
3. The crystals of $CaCO_3$ may occur in either of two forms, calcite or aragonite. Which is the more stable of the two forms? Which is the more soluble? Does this stability-solubility relationship hold true for other compounds that occur in more than one crystalline form?
4. The orgin of fine-grained nonfossiliferous limestone is difficult to determine in most localities. Are there any clues in the composition of the limestone of your area that would indicate how it was formed?
5. At what rate do stalactites form?

Calotropis

Calotropis is one of the most common plants native to India. There have been attempts to extract natural rubber from its latex, botanists and entomologists have been fascinated by its trap-type pollination mechanism, and decorators have used the dried seed pods in fall and winter floral arrangements. But aside from being a bane to the gardener and the sole food source of many insects, Calotropis is of minor importance in our economy.

The seeds of the Calotropis are covered with long silken hairs. Could these fibres be used as an insulating fill for gloves or comforters? What is the thermal conductivity of the material? As an insulating material, how does the Calotropis fibre compare with kapok, cotton, and wool? Could these fibres be used to make paper? If acids are added to the latex of the plant, can the resulting product be used as rubber?

Coal

The various kinds of coal are complex mixtures containing free carbon together with a great variety of material derived from plant life, including mineral impurities. It is believed that during the *carboniferous* age the characteristic conditions of temperature, pressure, and world climate caused large masses of decaying vegetation to accumulate in congested forests. The decay process converted the cellulose, proteins, and lignin of the vegetation into peat. With the subsequent movements of earth, the peat was covered by minerals which in time produced the sedimentary rocks such as shale or sandstone. The pressure of the overlying strata and the residual decay created an increase of temperature in the peat which slowly converted it into coal.

1. What are the properties of coal by which the various forms may be classified and rated?
2. Prepare the by-products of coal by destructive distillation. Determine the percentage of coal gas, ethers, oils, tar, and coke in the different kinds of coals.
3. Coal is believed to have been formed by the action of heat and pressure on vegetation during millions of years. Can coal be produced from vegetation in the laboratory, under controlled conditions of temperature and pressure?
4. How do the different forms of coal vary in the quantity of heat that is released upon burning?
5. How effective are coke and charcoal as filters of impure liquids and gases? In what physical form is carbon most effective as an adsorber of gases and colloids?
6. What is the chemical content of the ash left after the burning of coal? Is the ash of coal different from the ash of wood?

Coins

The desirable properties of coins are resistance to wear and resistance to corrosion. The cost of the coin to the government should be equal to or less than the denomination of the coin. Gold and silver are good coin metals, but coins of low denomination are made of nickel, copper, and aluminium.

Many coins are stamped from alloys that provide the desirable properties better than the pure metal. For example, gold coins are 90% gold and 10% copper, silver coins are 90% silver and 10% copper, and nickel coins are 75% copper and 25% nickel.

1. Can the rate of wear (say gms./year) of an issue of coin be determined by weighing circulated samples of the coin over a period of several years?
2. How do coins made of the various metals differ in the rate, pattern, and chemistry of their corrosion?
3. Can the rate of exchange of a nation's currency be determined by the value of the metals used in its currency? For example, at what denominational level does a nation's coinage change to silver? Is there any correspondence between weight and value in copper coins?
4. Archimedes found out whether or not the crown of a king of Syracuse was pure gold by determining the specific gravity (by flotation) of the crown. Knowing the specific gravities of the pure metals (listed below) what can you determine about the composition of the coins?

Metal	*Specific gravity*
Copper	8.92
Silver	10.5
Nickel	8.90
Gold	19.3
Aluminium	2.70

By what other techniques can you determine the composition of a coin?

5. What tests can you develop for the detection of counterfeit coins?

Collections

Generally, collections themselves do not constitute science projects. Well-classified and extensive collections of minerals, fossils, insects, or flowering plants, however, are enjoyable to make and often are useful in solving science problems. A fossil collector might want to develop a system for the classification of crinoid rings where available keys in his locality make use only of the features of the rare crinoid head. Collectors of flowering plants might determine whether family grouping is possible on the basis of pollen structure. Collectors of insects might investigate the extent to which insects can be identified by using wing venation as the only distinguishing characteristic. An examination of a collection can raise many questions:

1. How do specific gravity, colour, structure, hardness, and mineral composition of the rocks in a region compare?
2. What rocks and minerals seem to be most abundant in the various samples collected from the beds of different streams?
3. How do the characteristics of feathers, such as colour, heat conductivity, or size vary among birds?
4. Can you identify birds on the basis of nests that have been collected?
5. Can the feeding habits of a bird be correlated with the structure of its beak?
6. What families and classes of insects have you collected? Can you group insects on the basis of wing structure

A mere collection of insects does not make a scientific investigation. It does, however, enable the researcher to pursue such questions as: What are the size variations among beatles of one species in one locality? or what structural differences occur among the sexes of butterflies?

and venation only?

7. Does the position of a leaf on a tree determine the leaf's size and intensity of green colouration?

Combustion

The combustion process proceeds when a fuel is oxidised, energy is released, and by-products are formed. The rate of the reaction depends upon many factors, including the surface area of the fuel, the amount of oxygen supplied, and the nature of the fuel.

1. In what ways does the surface area of the fuel affect the rate of combustion?
2. How is the rate of combustion affected by the supply of oxygen?
3. The flame or sparking during combustion occurs when the temperature of the fuel rises to a definite temperature, called the *kindling temperature* or *ignition point*. What are the kindling temperatures of kerosene oil, different varieties of woods, and paper?
4. Does the rate of oxidation affect the chemical nature of the by-product?

5. In a very real sense all organisms are burning systems. Food (fuel) and oxygen are combined to provide energy for the plant or animal, while by-products are released. In humans the "flame of life" can be detected in a constant body temperature of 98.6° F.

a. Does the body temperature really remain constant over a period of a month or are there rhythmic variations?

b. Does body temperature shift from normal after taking meals, after exercise, or during sleep?

c. What are the body temperatures of cows, buffalo, dogs, and other mammals?

d. Does the body temperature remain the same throughout the day and night?

e. Does external temperature have any effect on body temperature?

Composite Motion

●

If you are the steady type, the above dot is motionless with reference to you. If you are holding this book while in a moving vehicle, the dot has a magnitude and direction of motion with reference to the ground. If the vehicle is bouncing and swaying, two more vectors may be added. The dot is also moving with reference to the earth, the solar system, the galaxy, and the universe which are all in motion. With reference to a fixed point in space, what are all the component motions of the above dot?

Many common and puzzling phenomena of relative motions can be investigated. Suppose, for example, you are a passenger on a horse cart moving through a flooded street. A car moving along side of you may appear to be stationary, while stationary objects may appear to be moving. What accounts for this "confusion"? Can similar situations be contrived in the laboratory? Can you determine the relative velocity of objects?

How does the insect fauna of Rajasthan differ from the insect fauna of Madras or Assam?

Concrete

Some labourers were mixing concrete in a tub for the construction of the roof of a bungalow that was being built. After a while someone noticed there was a big fire in one of the nearby bungalows. The labourers rushed to that bungalow to rescue the persons who were inside and to control the fire. One of the concrete mixers stayed behind and brought sugar and mixed it with the concrete before going to the burning house. After the fire rescue squadron reached the spot and the fire was under control, the labourers returned and continued their work. But several hours had passed.

When the labourer who mixed the sugar into the concrete was asked the reason for this action, he said it was to delay the hardening of the concrete. He did not know how long the workers would have to stay away and he thought the mixed concrete would probably harden into a lump and stick to the tub. The labourer did not know why the sugar acted as it did. He knew only that the procedure was recommended by a building construction technician. He also knew that the sugar treatment worked.

1. How does sugar affect the setting of concrete?

2. How do changes in environment affect the rate at which concrete hardens?

3. Are there substances that will counteract the actions of sugar in concrete?

4. What other substances retard hardening?
5. Are there substances that will increase the hardening rate of concrete?
6. How can concrete be coloured?
7. How can concrete be given special properties to make it more effective in binding bricks?

Co-operative Ventures

Certain problems can only be solved through the co-operation of observers geographically removed from one another. A science student interested in insect collecting may get some insects from correspondents of the same country or from different countries. The study of the migration of birds can be done in different zones of countries by various workers of the project. Variations in rainfall within a meteorological district for a period of one year might reveal a range of reliability of a single 'official' weather observation station. Projects in astronomy, such as studies of the duration of nights and days, the phases of the moon, or the tracking of artificial satellites, may be carried out through the shared records of many observers. A few science clubs distributed over a large area may take up such projects jointly. Sometimes information is available from official sources especially set up for certain projects, such as the rise of water in rivers at different places during rainy periods.

There are occasions when a researcher in a university seeks the help of student workers who are interested in the same field. Data and materials may be shared. A mutual venture can be very helpful to all of the workers concerned.

Corrosion

Corrosion is the process that involves the destruction of materials through slow chemical and electrochemical reactions that occur between a material and its environment. Examples include the rusting of iron, the tarnishing of silver, the surface oxidizing of aluminium. Corrosion proceeds with a flow of electricity between certain areas of a metal surface through a solution (electrolyte) that is capable of conducting an electric current. The electrochemical action causes destructive eating away of the metal at the place where the current leaves the metal and enters the solution.

Thus during the rusting of iron, the electrolyte is in the moisture. The numerous cathodes and anodes on the surface of the metal may be caused by the impurities in the metal, the lack of homogeneity of impurities, the rough surface of the metal, or the combined effects of all of these.

In the corrosion of iron, the hydroxyl ions (OH^-) from water combine with ferrous ions at the anode and form ferrous hydroxide which is soon oxidised by the oxygen in the solution to form ferric hydroxide. The ferric hydroxide accumulates on the surface, forming what we call rust.

1. Under what environmental conditions can iron be made to rust most rapidly?
2. Does rusting take place more rapidly on a rough surface than on a smooth surface of the same metal?
3. Can the corrosion of iron be controlled if water that has not been aerated is used?
4. An iron piece, when immersed in a copper sulphate solution, becomes coated with the copper. A similar piece of iron remains unaffected in copper sulphate solution if it is dipped in nitric acid before being dipped in the copper solution. How permanent is the "protective coating" put on iron by nitric acid?
5. What are the rates of rusting of iron alloys?

For further study see: F.L. Laque, T.P. May, H.H. Uhlig, *Corrosion in Action*. The International Nickel Company, 67 Wall Street, New York 5, N.Y. 1955.

Detergents

Detergents are those materials that reduce the surface tension of liquids in which they are dissolved. For example, the surface tension of pure water in air at 20°C. is reduced from 73 dynes per cm. to 25 dynes per cm. by making a 10% soap solution. The lowering of surface tension helps in the formation of lather. This also helps the penetration and wetting of the material to be cleansed. The dirt particles are surrounded by the lather and washed away through rinsing.

The increased use of synthetic detergents has created many problems. One of the major impacts has been on the efficiency of sewage treatment, since the presence of foam decreases the rate of decay of wastes. Water that is loaded with detergents may be harmful for plants if used for irrigation, and aquatic animals may also find this water to be toxic.

1. How do detergents in water affect the growth of green plants, fungi, or algae? Is there a definite tolerance limit of these plants for detergents? What is the tolerable concentration of detergents in water for plants?
2. How are the life spans of small fishes influenced by the presence of detergents in water? Which detergent is the least harmful to aquatic animals?
3. Can synthetic detergent wastes be chemically or physically treated to reduce the bothersome odour and foaming characteristics?
4. Which are the best soaps available in the market with regard to lather formation and ability to dislodge and hold dirt and soil clumps in suspension.
5. How effective a method of washing is beating clothes on rocks?
6. What is the most suitable temperature for washing clothes?
7. What kinds and proportions of fats and oils combine with caustic soda to produce the best kind of soap?

Dielectrics

A *dielectric* is a body through which, or a medium in which, electric attraction or repulsion may be sustained. Thus, glass is dielectric, because unlike charges on opposite sides of a plate of glass attract each other. Likewise two charged bodies immersed in oil or in liquid nitrogen exhibit mutual electric force (though less than in a vacuum); hence these substances are dielectrics. Dielectrics are always insulators; a good conductor completely screens off an electric field.

The condenser is the usual form of apparatus for studying the comparison and application of dielectrics.

A capacitor is a device for storing electric charges and is used in most electronic devices. In its simplest form it consists of two metal plates separated by air. The maximum charge that can be stored in the capacitor depends on:

a. the area of the plates;
b. the distance between the plates;
c. the nature of the dielectric separating them.

The dielectric constant of each substance may vary as the environmental conditions change.

1. How is the dielectric constant of various materials affected by extreme temperature and severe vibrations?
2. When two liquid dielectrics are mixed, how does the dielectric constant of the final solution compare to those of the pure liquids?
3. When a dielectric is placed in an electric field, how does the shift of electron take place?

Earthen Pots

Since the earliest archaeological times earthen pots have been very much a part of Indian life. Today earthen pots are used for cooking, for storage, and for keeping water cold. Ancient peoples are known to have used earthenware for smelting (extracting metal from ore) and for constructing houses. All of these uses, and undoubtedly more, depend upon certain special properties of the earthenware and of the materials of which it is made.

Consider the following scientific problems that have been inspired by thinking about the properties and uses of certain pots.

1. How does the conductivity of earthenware compare with the conductivity of metal, glass, wood, and other substances of which containers may be constructed?
2. Under what atmospheric conditions are earthen pots most effective as water coolers? What shapes, porosity, colour, size of mouth, and other structural characteristics are most effective for water cooling?
3. How resistant are earthen pots to thermal shock? (What is the fastest or slowest a pot can be heated or cooled before cracking or shattering occurs?)
4. How do colour, lustre, and finish affect the thermal properties of earthen pots?
5. Sometimes earthen pots are used as percussion or stringed musical instruments. (A percussion instrument is one that is played by striking.) How do the musical notes produced vary with the dimensions of the vessel?
6. What are the comparative strengths of earthen vessels of different compositions?
7. Is the cooling the same when a jug is (a) filled partially; (b) filled wholly; (c) covered; and (d) open?
8. How does the rate of cooling vary with (a) water; (b) salt solutions; (c) milk; (d) volatile liquids like alcohol and petrol?
9. It is a common belief that an earthen pot (a jug) should not be allowed to dry up completely. How would complete drying influence the capacity of a jug to keep water cool?

Earthquake Waves

When tensions within the earth are suddenly released, energy is transmitted by waves in all directions. These earthquake or seismic waves are of several kinds. There are the fastest travelling longitudinal, or P-waves, that pass through solids, liquids, and gases; the slower travelling transverse S-waves that will pass through only solids; and the transverse L-waves that travel over the surface of the earth and cause most of the property damage associated with earthquakes.

Study and analysis of earthquake waves as recorded by seismographs are useful in locating earthquake foci, determining the magnitude of earthquakes, and building up a model of the internal structure of the earth.

1. What knowledge about an earth-

Geophysicists study seismograms to answer questions about the location and magnitude of earthquakes. These records are also useful in developing a model of the earth's interior.

quake can be gained from the study of a single seismogram?

2. How can the record of an earthquake on seismograms be used to calculate the location of the earthquake?

3. How sensitive are homemade seismographs?

4. Can models be developed to demonstrate the properties of seismic waves as they are reflected, refracted, and absorbed within the earth?

5. What relationship exists between the waves observed on land and the seismic sea waves that are often observed in association with earthquakes?

Earth's Magnetic Field

At Columbus, Ohio, U.S.A., the earth's magnetic field is so strong that if a single wire loop were to enclose an area of one metre square and if it were rotated at 3600 revolutions per minute, it would generate a peak voltage of the order of 0.01 volts. If the rotating coil had 100 loops, nearly one volt would be produced. These relationships might be used to measure daily or hourly variations in the earth's magnetic field.

Another relatively simple method of determining the direction and magnitude of the earth's magnetic field utilizes a Helmholtz coil, a magnetic compass, an ammeter, and a variable source of current.

1. Are there daily variations in the earth's magnetic field?

2. Are there hourly variations in the magnetic field of the earth?

3. Are variations in the earth's magnetic field related to buildings, large bodies of water, mountains, and similar variables?

4. Does weather affect the earth's magnetic field? Do variations, if there are any, in the earth's magnetic field affect the weather?

5. Does the relative position of the moon affect the local magnetic field?

Earthworms

All organisms have one outstanding characteristic in common—life. The study of an organism is very helpful in understanding other living things. It is desirable, therefore, to select as subjects for research those organisms that are abundant, available in all seasons, inexpensive, easily cared for, and not subject to emotional attachment. The earthworm is one such organism.

After knowing the general anatomy and physiology of the earthworm, the worker can direct his efforts to discover solutions to such problems as:

1. Does an earthworm emerge from the soil after a rain to avoid drowning?

2. How does the locomotion of an earthworm compare with the locomotion of a snake or a nematode? What is the normal rate of the locomotion of an earthworm? Is it capable of moving at the normal rate on slippery surfaces as well as on very rough surfaces? What change occurs in the rate of locomotion of earthworms while trying to escape from enemies? Can earthworms climb?

3. Can an earthworm regenerate a normal whole body after being cut behind its clitellum?

4. How does the pulse rate of the dorsal blood vessel vary with temperature?

5. What are the temperature tolerances of earthworms?

6. How do earthworms respond to stimuli such as light, acidity, temperature, sound, and direct electric current? How sensitive are earthworms with regard to touch, hearing, and sight?

7. How does the blood of an earthworm compare with human blood, structurally and chemically?

8. What parasites infest the posterior region of the coelom of earthworms?

9. How do earthworms affect soil?

Electrolysis

When a direct current is passed through an electrolytic solution, ions are liberated. The positive ions go to the cathode and the negative to the anode.

The mass of ions liberated is directly proportional to the quantity of electricity. If the same quantity of electricity is passed through different electrolytic solutions, the mass of ions liberated will be directly proportional to their chemical equivalent weights—*Faraday's law of electrolysis*.

1. How does an alternating current affect the mass of ions deposited on the electrodes?

2. Which salts can be decomposed in an electrolytic cell?

3. Does the surface area of the cathode in a copper sulphate solution influence the deposition of copper ions?

4. How does the temperature influence the deposition of ions?

5. What are the differences in optimum conditions of current, temperature, concentration of electrolyte, and nature of electrode for metals such as copper, chromium, and nickel when used for electroplating? What causes these differences?

6. "Iron plating" is not mentioned in textbooks. Can a substance be plated with iron?

7. What happens to the cathode of brass or copper while (or after) it is being plated with nickel on only one side?

Electro-osmosis

Water is known to move through a porous material toward the cathode when an electrical voltage is applied to the electrodes in the porous material. This phenomenon is known as *electro-osmosis*.

Electro-osmosis has been used to stiffen wet earth while excavations were being made.

1. Will electro-osmosis occur with pure water?

2. Will other liquids undergo electro-osmosis?

3. What voltage is necessary for electro-osmosis?

4. Would the use of electro-osmosis be practical to stiffen muddy football fields or playgrounds?

Electroplating Alloy

The electroplating of a metal from a solution of its ions is an easily observed phenomenon. Copper plating requires only a solution of a copper salt, a suitable electrode, and a source of direct current for the experiment.

If more than one metallic ion (cation) is present in a solution, you might expect the deposition of several metallic elements at the same time. If this occurred, it might be possible to electroplate alloys directly on base metal. Actually this has been done, but many variables can greatly affect the expected reaction.

In experimenting with the electroplating phenomenon, it is generally advisable to use a graphite cathode to minimize chemical side reactions. Salts of such metals as nickel, copper, bismuth, cadmium, and silver are especially adaptable to these experiments.

1. Is there a minimum voltage at which electroplating will occur?
2. Does the negative ion (anion) affect the deposition of metallic elements at the cathode?
3. If two metallic elements can be plated simultaneously, can a mixture of three or four be deposited in the same manner?
4. If two metals are plated together, does the plate have the properties of an alloy or a simple mixture of elements?

Energetic Electrons

Interesting visual effects are noted when a high-voltage electric discharge is passed through a tube from which air is being steadily removed by a vacuum pump. The tube must be strong enough to withstand the pressure difference, and observations must be made in a darkened room. The effects are most pronounced when the applied voltage is direct current. The appearance of alternate bright and dark regions requires some detailed explanation.

The same tube and discharge could be used to study chemical effects. If the electrodes are made of iron, only one of them is observed to corrode rapidly. Other chemical effects might be noted by replacing the air with mixtures of methane, ammonia, and hydrogen; after the electrical discharge had been continued for some time, amino acids (the building block of proteins) were found to be present. One hypothesis to account for the origin of life on earth has been based on this phenomenon.

Certain crystalline substances show fluorescence when subjected to an electric discharge, while others undergo a permanent change in colour.

(CAUTION: X rays may be generated whenever high voltage electrons strike a target.)

1. Specifically, what amino acids can be produced by electric discharge?

(CAUTION: Avoid explosive mixtures of gases.)

2. Do the various visible effects, such as the dark regions, occur at specific pressures? If so, why?
3. Since the electric discharge is a stream of energetic electrons, what chemical changes could be expected to occur in crystals?
4. What energies must the electrons acquire before chemical changes occur in crystals? Is the air pressure critical?
5. Can the bombarding electrons be directed, by a magnetic field, to hit the target crystals more effectively?
6. How are organic compounds affected by bombardment with energetic electrons?
7. Is the optical activity of certain compounds affected by bombardment with energetic electrons?

Erosional Agents

Erosional agents wear away the land in a very specific fashion. That is, materials are constantly being removed from areas of high elevation and transported to areas of lower elevation by the various agents of weathering: wind, water, ice, and temperature change. The individual and combined processes of erosion are the primary surface agents in the sculpturing of topographic features.

1. What are the causes and effects of irregularities within a river bed? Model rivers may be built to duplicate natural conditions.
2. Can you develop a device to study the influence of running water on soil erosion?
3. Is the depth of the water table influenced by the porosity of the bedrock, the amount of precipitation, or the temperature of the air? What other factors might influence water table depth?
4. Prepare a profile sketch showing the relationship between the position of the water table and the surface topography of the region.
5. Are the minerals from an eroded surface grouped according to weight or size of particle in the erosional deposits?
6. Collect a sample of fine and coarse sediment that has been transported by wind and mix it with some sand obtained from a desert, from the bed of a dry river, and from the bottom of a well. Allow the collected heap to be blown by a fan.
   a. What is the maximum size of particles that can be transported by wind produced by the fan?
   b. What is the relationship between the wind velocity and the movement of particles?
   c. What is the rate of transportation of particles by the wind?
   d. Would the wind velocity that is required to initiate movement be greater or less if the particles were of uniform size?
7. Do the bricks and stone on one side of a building appear to be eroded by wind more than the other sides?

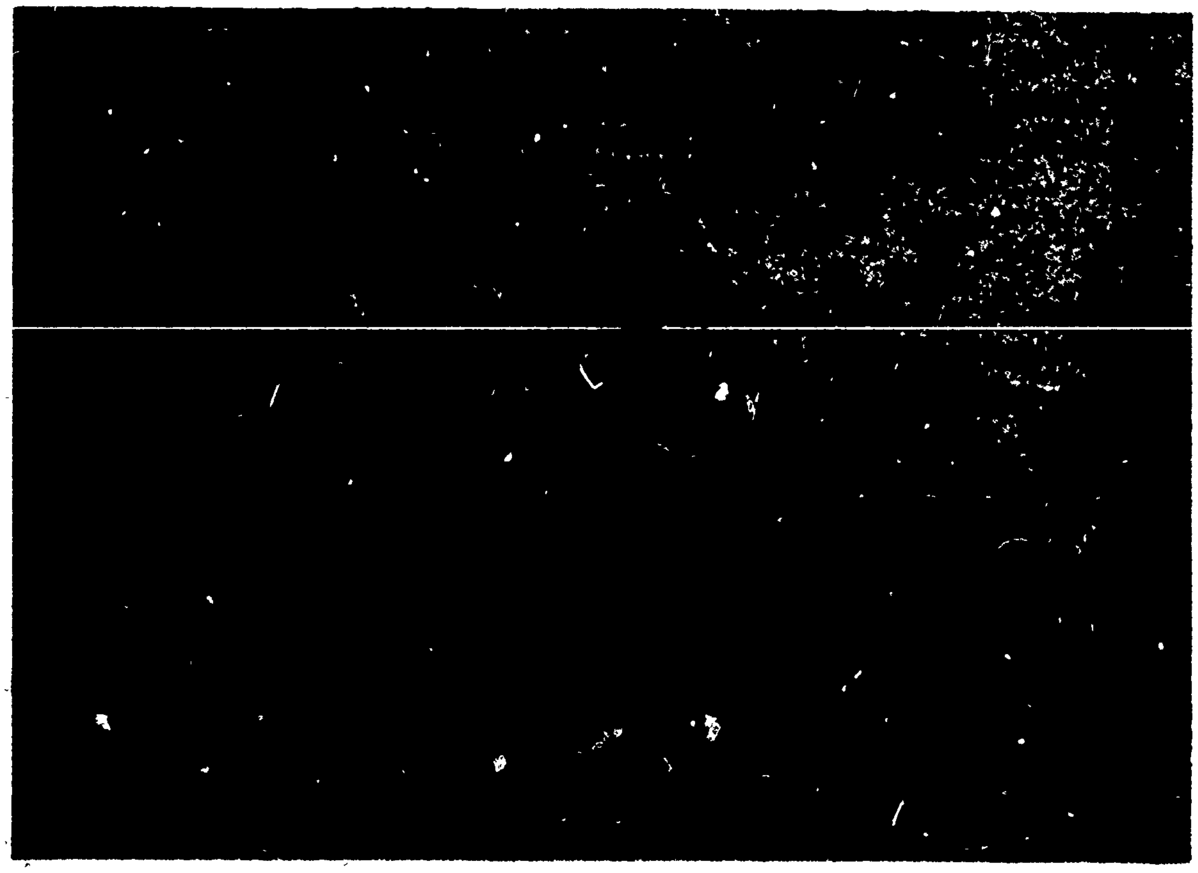
Fallout

Any dust that settles from the atmosphere can be termed *fallout*. People often associate fallout only with the radioactive dust produced by nuclear bombs that are tested in the atmosphere. However, atmospheric fallout may be due to many causes. The smoke from chimnies of big factories and industries, volcanoes, meteors, and the transportation of particles by wind contribute to fallout.

We usually regard dust in the air as undesirable. But experiments have shown that small dust particles are an essential element in the formation of clouds. Droplets of moisture form around dust particles and the droplets form rain and other forms of precipitation. The beauty of the sunset is due to the scattering of sunlight by tiny dust particles.

The presence of atmospheric fallout may be determined with a microscope. Or it may be seen on the surface of calm water in a pond or a can. Even the occurrence of dust in a closed room is due to atmospheric fallout.

1. How effective is rain in removing dust from the troposphere?
2. What are the shapes of particles in a fallout when examined with a microscope? (Particles can be collected by exposing thinly greased microscope slides to the open atmosphere.)
3. What can be said about particles that show magnetic properties? What evidence is there that these particles are little meteorites?
4. How much fallout occurs in an area of one square foot?
5. Is all airborne dust effective in providing condensation nuclei for rain?
6. If you create an artificial volcano by igniting ammonium dichromate what kinds of particles fall first during the fallout?
7. How does the fallout in remote villages differ from the fallout in cities? Can the fallout in Bombay be distinguished from the fallout in Calcutta, Jaipur, Delhi, or Chandigarh?



What is the form of the curve when the density of fallout is plotted against horizontal distance from the cone of a model volcano?

Fluid Jets

A balloon filled with coloured water will emit a visible stream when pinched slightly. The more you press the balloon, the longer is the stream of water. The discharge of a stream of fluid through an opening (orifice) is the jet phenomenon. A liquid jet can be discharged when submerged either into a gas or a liquid.

Jets are of importance in engineering; this phenomenon is also a basis for the operation of fire extinguishers, paint sprayers, and syringes.

A jet of water discharged horizontally follows a downwardly curving path on account of the attraction of the water to the earth due to gravity. The trajectories of fluid jets can be controlled by varying such things as the dimensions of the orifice, the nature of the fluid, or the force applied to the confined liquid.

1. All other conditions being constant, at what inclination will a jet of water travel a maximum distance? Is the range for other liquids the same at this inclination under identical conditions?
2. How is the maximum range of fluids affected by varying the diameter of the orifice?
3. If the liquid is projected vertically, how does the height of the fountain compare for different liquids when projected under the same conditions?
4. Suppose there are two orifices, with the diameter of the first being exactly half of the second. If the same liquid is projected under identical conditions through the two orifices, what will be the relationships of the amounts of fluid ejected from each?
5. How can the velocity of a fluid jet be measured?
6. To what uses can fluid jets be put? How can this principle be utilized in the construction of water rockets?

Freezing-Point Depression

The freezing point of a liquid is lowered when a substance is dissolved in the liquid. One mole of sugar dissolved in one litre of water produces a solution that freezes at —1.86°C. A sodium chloride solution of the same mole concentration freezes at —3.42°C. The difference is explained partly by the dissociation of sodium chloride. In other examples, the solute produces a freezing-point depression quite different from that predicted by the *Arrhenium Theory* of electrolyte dissociation.

1. What solutes produce abnormal depressions of the freezing point? Are there any that produce no depression?
2. Do solutes produce the same depression for different solvents?
3. How do solutes depress the freezing points of solutions?
4. What effect, if any, do suspended or colloidal substances have on the freezing point of a liquid?
5. Do melting points of frozen solutions correspond exactly with the freezing points of the solutions?
6. Can molecular weights be determined by using data from freezing-point depression experiments?
7. How is it possible for a mixture of

crushed ice and table salt to produce a lower temperature than that of the ice alone? What is the lowest temperature that can be produced by this mixture?

Gauss Effect

Bismuth metal varies greatly in electrical resistance when it is in a magnetic field. This effect, known as the *Gauss effect* is shown by many metals. The direction of the magnetic field also influences the resistance.

1. Could this effect be utilized in making a magnetic-field strength gauge?
2. Which metals exhibit great and small Gauss effect?
3. Do electrolytic solutions show a Gauss effect?
4. What model of the structure of metals could account for the Gauss effect?
5. Why does the Gauss effect occur?
6. Do other parameters influence the magnitude of the Gauss effect (e.g., temperature or vibration)?
7. Is a gaseous conductor (a low-pressure neon tube) subject to the Gauss effect?

Hair

Generally speaking, every human culture considers hair an element of beauty. Some people grease their hair while others may use many types of shampoos, cosmetics, and perfumed oils. A few people in India, especially those who belong to villages, use clay, curd, and skimmed milk to clean their hair. In western countries, the bleaching and dyeing of hair is very popular. These treatments may cause some changes in the physical and chemical nature of the hair.

Hair is important for reasons other than beauty. Hair on the body of different animals gives shelter to many animals and some plants. To a criminologist hair is useful in identifying an individual. In addition, hair is used by people in many spheres of their lives, e.g., for insulation and clothing, in violin bows, and in different types of brushes. The continual growth of hair is a source of income to barbers. Thus, hair is certainly very much a part of our social and economic lives. The following are some interesting investigating guidelines for research:

1. Which grows faster in man, body hair or scalp hair? Does periodically cutting the hair have any effect on its rate of growth?
2. How do the following properties of hair compare microscopically?
   a. Structure of eyebrow hair and scalp hair.
   b. Dyed and naturally coloured hair.
   c. Curly hair and straight hair.
3. Does the tensile strength of hair vary with the age of the person?
4. What are the effects of alcohol, greases, shampoos, hair oils, and such cosmetics on growth, manageability, lice, dandruff, and colour?
5. Is hair an effective fertiliser?
6. How does a fingernail differ from a hair? What is a horn?
7. What is the action on hair of the different hair-removing chemicals available in the market?
8. What is the growth pattern of hair inside the nose where air is filtered by the hair?
9. Can genetic laws explain the following:
   a. Widow's peak.
   b. Extensive hair growth on the outer edge of the ear.
   c. Hair on segments of fingers.
   d. Thick growth of eyebrows and the joining of both eyebrows.
10. Why does a person sometimes have his hair fall out after a serious illness, especially typhoid? In what diseases and in what percentage of those afflicted does the hair fall?

Heat Absorption in Plants

The ability to absorb heat from the sun differs among plants. As the external temperature rises, the rate of transpiration of a plant increases. Transpiration tends to cool the plant.

The heat absorption abilities of a plant can be determined by noting the temperatures of the different organs of the plant after a definite interval of exposure to the sun.

1. How much heat is absorbed by the fruit on growing plants when exposed to the sun?
2. Which part of a plant absorbs more heat when all parts are exposed equally well?
3. Do the temperatures of plants tend to remain within a certain steady range? If so, what is the steady range in each case?
4. What are the temperatures of stem, leaf, and fruit under the following conditions:
   a. When leaves are greased on both surfaces.
   b. When leaves are allowed to transpire.
5. How much heat energy is dissipated by the plant through transpiration?
6. If a plant is placed in a darkened room, what is the effect on the rate of transpiration of varying the temperature of the air in the room?
7. What basic anatomical and physiological differences exist between cold-climate and warm-climate plants with regard to their heat-controlling apparatus?
8. Is the heat absorption ability of a plant in some way related to the weight of the plant? What type of curve would be obtained by plotting the temperature rise against the weight of a plant?
9. Is the time required for fruit to ripen on the plant related to air temperature?

Insecticides and Repellents

Some chemical substances are effective in killing or repelling economically injurious insects. In addition to toxicity, the effectiveness of these chemicals depends upon many factors. Some strains of insects have greater resistance to an insecticide than have other strains of insects.

Where it is not practical to kill insects, repellent measures are often used. Certain intensities of light, frequencies of sound, and specific chemicals repel insects.

Careful observation of cockroaches revealed that they frequently lick the bottoms of their feet. This led to the discovery that roaches can be controlled with a stomach poison spread on the floor close to the wall. Can you explain why the poison is more effective when placed close to the wall?

1. What is the comparative effectiveness of DDT, Gammexane, and Flit in killing house flies, and mosquitoes?
2. Is it possible to repel insects with sounds of certain frequencies?
3. What are the most suitable conditions for the application of DDT or Flit against flies and cockroaches?
4. How long after application does a specific chemical have its greatest impact on killing or repelling insects?
5. What are the most effective procedures for ridding a large institution such as a hospital or hostel of bed bugs?

Interference Colours in Oil Spots

When the ground is wet after a shower of rain you can often see coloured patches on the dark asphalt of your roads. Sometimes there are patches as large as two feet in diameter and made up of concentric coloured circles. These patches are formed by drops of oil from passing cars and on certain days and on certain roads they can be very beautiful. Each drop spreads out into a very thin film over the water and the combination of light reflected from the upper and lower surfaces of the film produces interference colours called *Newton's rings*.

1. Can you find a relationship between the specific colours of an interference pattern and the corresponding colours in the rainbow spectrum?
2. What explanation can you make for nonpigmented colours of fishes, butterflies, and birds?
3. How do the patterns of colours produced on a water surface by a drop of paraffin, a drop of turpentine, and a drop of oil compare?
4. Beautiful colours can sometimes be seen on the tarnished copper of the funnels of locomotives and motor engines. Is this because the copper has become hot and subsequently oxidised, or has a layer of sulphide been deposited on the funnel from the atmosphere and combustion gases, or is there still another explanation?
5. What relationship can you develop between the colours and the thickness of the oil spots as you change the angle from which you view the film?
6. Under what conditions does a thin film appear black in the centre, then red when the film is rotated?

Lichtenberg Effect

A dielectric (plastic or hard rubber) in the form of a plate is touched at different spots with positively and negatively charged rods. This produces areas of different charge on the same plate. If a mixture of powdered red lead oxide and sulphur (flowers) is shaken and then sprinkled on the plate, the lead oxide adheres to the spots touched by the negative rod, while the sulphur adheres to the other areas. This is sometimes referred to as the *Lichtenberg effect*.

1. Why are the two materials attracted to the specific areas?
2. If magnesium or copper oxides were used in place of lead oxide, would similar results occur? What about other combinations?
3. Can a practical application be made of this phenomenon?

Lubricants

Industrial machinery would soon slow and ultimately stop if the supply of lubricating oils became depleted. Every piece of machinery that moves, from automobile engines to wrist watches, requires proper lubrication.

Recent commercial developments feature motor oils that maintain a given viscosity over a wide temperature range and automobiles that can go 4000 miles between oil changes.

1. Can old oil that has been drained from automobile crankcases be reprocessed for use, or is it really worn out?
2. Do lubricants vary in effectiveness if the part to be lubricated is magnetic?
3. Does water, or any other substance, cause a noticeable decrease in the action of a lubricant?
4. How are the lubricating proper-

tics of oils affected by high pressures? Is the same effect noted for solid lubricants such as graphite and lead oxide?

5. Does the phenomenon of thixotropy (liquefication of a gel, by vibrating forces such as shaking and ultrasonic waves, and its setting again on standing) have importance in the all-temperature oil?

6. Is the effectiveness of a lubricant a function of molecular size, weight, or of molecular geometry?

7. How do the coefficients of friction between various objects change with lubrication?

Magnets

Permanent magnets and electromagnets are common objects in the secondary school science laboratory. As far as we know, the human senses are unable to detect a magnetic field. Yet magnetic fields are common; for example, you are probably familiar with such things as bar or horseshoe magnets, the field enveloping an electrical current, and the magnetic field of the earth.

There is a tribe in Africa that believes that wearing a magnet on a necklace will insure the good health of the wearer. Most of us believe that magnets contain little magic. However, a note of mystery remains about magnets and the forces surrounding them.

1. Can animals detect a magnetic field? If iron filings are placed in the aquarium environment of a crayfish, the animal's sense of balance will be disturbed by the magnetic effects. The effect is noted after the crayfish molts. Can you explain this?

2. Is the growth of plants affected by a magnetic field?

3. Does the presence of a magnetic field affect the formation of crystals?

4. Are chemical reaction rates affected by magnetism?

5. Is the attraction between magnets affected by the substance between them (the substance could be air, water, or glass)?

6. What is the most powerful magnet that can be constructed?

7. The magnetism of a bar magnet is lost by heating, which is called the *curie effect*. If you heat a bar magnet to a definite temperature and then bring it back to the room temperature, how is the pole strength of the magnet influenced?

8. When a powerful bar magnet is rubbed against a steel bar, the steel bar becomes magnetised. Does the magnetism of the powerful magnet remain the same?

Mechanical Waves

Mechanical energy may be transmitted through a medium by means of waves. Gases and liquids (fluids) can transmit longitudinal waves, while solids are capable of sustaining longitudinal and transverse waves. The most familiar mechanical waves are sound waves.

Which minerals are in the rocks in your area?

1. The speed of sound in a metal varies directly as the square root of the elasticity and inversely as the square root of the density. How can the speed of sound in small alloy metal rods be determined?

2. Does the above relationship apply also to gases? to liquids?

3. We know sound can be reflected. Can it be refracted? Can sound lenses be constructed to focus mechanical energy?

4. Is it possible for a sound to be destroyed by interference?

5. The crack of a whip is said to be a sonic boom. Can this be verified?

Metal Toxicity

The copper ion is known to be toxic to certain microorganisms. A copper coin in an aquarium is said to prevent the growth of algae, and copper sulphate when introduced into ponds kills protozoa that cause bad odours and tastes in drinking water. During World War II, an experimental treatment for fungus infections of the feet was to electroplate copper on the infected foot. Lead and mercury are metals known to be dangerous poisons.

1. To what extent does metallic copper embedded in agar retard the growth of pure cultures of mold?

2. Do other heavy metal elements inhibit mold growth? To what degree?

3. Does a mouse whose tail is immersed in an attached tube of mercury show any response to the metal absorbed through the skin?

4. Are heavy metallic ions absorbed by land plants?

5. Is soil that contains arsenic fatal to plants?

Minerals

Minerals are natural inorganic substances. They may be either elements or compounds. Each mineral has definite characteristics, such as weight per unit volume, hardness, colour, and crystalline form.

Minerals are extracted from the earth's crust which is composed of many kinds of rock, each consisting of one or more minerals. Rocks have no particular form or colour, but are characterized by their mineral components.

1. Granite is a common rock made up largely of feldspar, quartz, and mica. How do the crystalline structures of the minerals in various samples of granite rock compare?

2. Can you make models of the crystals of quartz, pyrite, garnet, mica, calcite, and other available minerals? How do the elements of symmetry compare in these minerals?
3. Do crystals grown in the laboratory bear much resemblance to the crystals of natural minerals?
4. Can a "mineral map" be prepared for a region?
5. Aquamarine and emerald are forms of the mineral beryl. What are the ranges of structure and composition in a sample of beryl?

Mountains

Mountains are formed by folding and faulting in the earth's crust, by erosion of plateaus, and by volcanic action. Mountain formation can be studied experimentally. Collect some clay slabs of different colours. Stack four slabs of clay on top of each other; press the sides of the clay layers inwardly with the hands until pressure causes the clay to buckle and form a hump. Pressure warps rock layers in the same manner as it buckles the clay layers. This illustrates mountain formation by "folding." (In place of clay, you can substitute packs of coloured paper, layers of sponge rubber, or coloured turkish towels.)

If you apply enough pressure to the clay layers, they will crack. This demonstrates mountain building by "faulting."

Valleys can be carved into the clay layers. Some mountains are the result of partial erosion of flat land or high plateaus. Such activity is usually accompanied by the gradual upward folding of the whole area.

Using an apparatus similar to that described above, can you duplicate the topographical features of your region? Geologists often conduct experiments of this type to test their hypotheses about how certain land forms came into being.

Onion
(Allium cepa)

The onion is an important vegetable crop of India. It is rich in vitamin B and contains traces of vitamin C, iron, and calcium. What are the onion's other constituents? What percentage of the onion is water? Pungency in onion is due to a volatile oil, allyl-propyl-disulphide. Big, white bulbs are less pungent than small and red bulbs. Can pungency of the bulbs be reduced by certain treatments (more water supply, less amount of sulphur) of the soil in which it grows?

The onion plant is quite hardy; it is even able to withstand freezing temperatures. However, at the prebulb stage mild temperatures result in the best growth, while relatively higher temperatures during the ripening stage are suitable for a good yield. How high and how low can the temperatures reach and still allow a plant to survive?

Shortages and excesses of water are harmful to onion plants especially in the prebulb stage. Do the intervals between watering have any effect on the higher yields?

The onion is not too exacting in its soil requirements, but it can not be grown in alkaline land. In what ways do the bulbs produced in light sandy soil and those produced in hard soil differ (other conditions remaining the same for both)? Soil enriched with organic matter and fertilisers produces heavy solid bulbs of superior keeping quality. Can the size of the bulbs of the small variety onion be increased by providing more nutrients, a sufficient water supply, and suitable space between rows and seedlings?

For seed production, bulbs are planted instead of seeds. Wider spacing between the rows and between the bulbs results in a higher yield of seed onion. Other requirements are the same. Which of the flowers produce heavier seeds with better capacity—the early flowers or the late flowers? Do the seeds of onions that are older than one year produce plants that are as healthy as those coming from seeds of onions less than one year old?

The amount of food stored in a bulb depends upon the extent of photosynthesis that has taken place in the green leaves. Can the quantity of food in a bulb be increased by providing artificial light to an experimental set of plants?

Opportunities in Special Geographical Regions

The peculiar climate and geology of a locality provide many opportunities for investigations in the fields of earth sciences, botany, and zoology. Oceanography is a science s..ted for residents in coastal regions, smog abatement is of special interest for urban students, while the study of causes of the formation of deserts is most meaningful to those who live near deserts. The alert student seeking a research project might consider investigating problems unique to his region. In addition to having the natural resources available, he will discover that the area has probably attracted specialists who may help in an investigation related to their field.

If your region is:

A. Metropolitan

1. How does the climate in the middle of a conjested locality differ from the reported norms established through observations at outlying weather stations?

2. What is the fallout rate in the city as compared with the fallout rate in the country? (Glass slides that are thinly coated with grease may be put at the tops of houses for some time and later studied under a microscope to reveal fallout.)

3. How effective is water purification? Is water as free from bacteria at a tap in your home as it is at the treatment plant?

B. Rural

1. How does the milk of buffalo, cows, goats, camels, and sheep compare with respect to fat content?

2. How does the soil of one village compare with the soil of another village with respect to the percentage of its constituents (air, water, minerals, and organic matter), water-holding capacity, and water-raising power?

3. Buffalo, cows, horses, and dogs show the interesting phenomenon of being able to return to their master's

Through chromatography one can separate large complex molecules. How many pigments can you find in chlorophyll, carrot juice, or ink?

house themselves if left at a distance far from his house. How can this ability be compared among different animals?

4. Which of the following fuels provides the most heat per gram, cow dung patties, coal, or wood?

C. Coastal

1. Consider studying the natural history of common but little-known marine invertebrates. After selecting and identifying a species or a group, problems can be identified regarding seasonal occurrence, abundance or density, food and feeding habits, variation, sex ratio, spawning habits, and growth rate.

2. What are the energy, structure, power, utility, and weathering action of ocean waves?

3. Sea salts are often publicized as being more healthful as a table salt than common iodized sodium chloride. Is there any basis for this belief?

4. How effective is the fisherman's procedure of "pit curing" in retarding spoilage of fish?

D. Mountainous

1. Is there a relationship between the elevation at which a person lives and the density of red cells in his blood?

2. What biological difference can be noted and explained in the plant and animal communities on opposite slopes of the same mountain or hill?

3. Through direct observations, how much of the geological history of an area can be reconstructed?

E. Desert

1. Is water the only need of barren soil in this area? Where mineral deficiencies or excesses or pH extremes exist, how can the condition most economically be corrected?

2. What are the effects of using soil conditioners such as Krilium on desert soil?

3. Do plants reflect the presence of specific minerals; that is, can growing plants be used as indicators of the presence of certain minerals?

4. What evidence is there in the belief that Indian deserts are "advancing"?

F. Glaciated

1. What information about a glacier, its direction of motion, speed, duration, mass, and origin can be deducted from observing the grooves in bedrock, moraines, erratics, and drainage systems?

2. What differences in soil chemistry, kinds of plants, and types of human communities can be noted on either side of terminal moraines?

Ozone

A large portion of the ultraviolet (UV) radiation coming from the sun is prevented from reaching the earth by the upper atmosphere. Without this filtering action, the intensity of ultraviolet radiation would make life on the earth's surface, as we know it, very difficult or even impossible.

The mechanism by which ultraviolet energy is absorbed involves the transformation of molecular oxygen (O_2) to ozone (O_3). Ozone contains more energy than ordinary oxygen and is generally more reactive. Traces of ozone, distributed by the natural circulation of air, are found throughout the atmosphere. Probably the chief cause of the hairline cracks that appear in the sidewalls of automobile tires is the reaction of ozone with rubber.

Ozone is formed by electrical discharges especially of the "glow" or quiet type. The peculiar odour associated with thunder storms and electronic apparatus is due to ozone. Ozone has been used to kill bacteria in water, and some attempts have been made to kill bacteria in the air by using small ozone-generating UV lamps. Ozone has been suspected of contributing to the formation of irritating smog.

1. Ozone will liberate free iodine from potassium iodide at room temperature, but ordinary oxygen will not. Can this fact be utilized to devise a quantitative test for the concentration of ozone in the atmosphere? If so, does the ozone concentration of the air vary from day to day?

2. How effective is ozone in killing air-borne bacteria?

3. Could ozone be added to the air intake of a gasoline engine to improve its performance?

4. At what level of concentration does ozone become irritating to plants and animals? This question can be investigated by maintaining plants and animals in jars containing various amounts of ozone.

Paper—Its Manufacture and Properties

Can you imagine how paralyzed a modern society would become if our supply of paper were to run out?

In addition to the currently common uses of paper such as for writing, printing, cleaning, and wrapping, many additional uses are being developed—paper clothing being one. Since the principal raw material for the manufacture of paper, wood fibre, is being consumed faster than it is being replenished, new sources of fibre must be found. What will these new sources be—grasses, banana stocks, or plastics?

The properties of the different kinds of paper are related to its many uses. Some kinds of paper must be absorbent, whereas other kinds must be waterproof. Some paper must be able to resist being pulled apart (high tensile strength), though it may be torn readily, and some kinds of laboratory filter paper must leave no ash when burnt, whereas minerals are added to the paper for weight and sheen.

1. How do the microscopic structures of paper fibres compare?

2. How does the quality of papers you manufacture from fibres of plants common to your locality compare with each other?

3. How do the tensile strengths of newsprint, magazine paper, wrapping paper, and cardboard compare? How do their resistances to tearing compare?

4. Paper produces sound when it is being torn. Can paper be conveniently categorized and identified on the basis of the sound produced when torn?

5. How many grams of water can be absorbed per gram of blotting paper, newsprint, and book paper?

6. How does paper compare with wool as a heat insulator, or with rubber as an electrical insulator?

Parascience

Parascientific phenomena are all those things and events that cannot be explained by contemporary science. They are phenomena that do not fit into the existing generally accepted scientific frameworks.

Parascientific phenomena are divided into two groups. One is the *paraphysical:* antigravity machines, or apparatus that will render objects invisible. The other is called *parapsychological:* mind reading, the mental control of a physical system, or well witching.

Much research has been conducted in the parapsychological subject of extrasensory communication (ESC). Investigators have sought to determine the sensitivity of individuals in obtaining information from other minds (telepathy), obtaining information from a material substance other than the brain (clairvoyance), and obtaining information about future events (precognition).

1. In a standard test for telepathy, the "sender" successively stares at 25 cards (five sets of five cards, each set being numbered from one to five). A "receiver" records the numeral 1, 2, 3, 4, or 5 each time the "sender" concentrates on the number of another card. In the end the receiver has a record of 25 numerals which can be checked against the cards. Left to chance alone, the receiver should average five of the 25 correct. A "sensitive" is a person who is consistently correct at least seven out of 25 times.

a. Can you find any "sensitives"?

b. Is "sensitivity" a genetic trait?

c. Are some persons better "senders" than others?

What scientific evidence can you collect that will test hypotheses about extrasensory perception?

d. Are husband and wife more telepathic than people who are strangers?
2. Can the mind be used to influence the number that comes up when dice are rolled?
3. Is plant growth affected by "wishing" for rapid growth?
4. Can it be proved that some persons (water witches) can detect the presence and location of subterranean water?

Photosynthesis

Photosynthesis by green plants alone prevents the rapid disappearance of all life from the face of the earth.

During photosynthesis the plants synthesize a high-energy organic compound (glucose) from two low-energy inorganic compounds (carbon dioxide and water) in the presence of sunlight and chlorophyll. The transformation of the low-energy compounds to high-energy compounds is caused by the utilization of light energy. Chlorophyll aids the formation of high-energy compounds. The high-energy compound prepared by the plants is a carbohydrate. Although the immediate product of the process is glucose, most of it is changed into starch and fats. The equation for the photosynthetic reaction is as follows:

$$6CO_2 + 12H_2O \xrightarrow[\text{sunlight}]{\text{chlorophyll}} C_6H_{12}O_6 + 6O_2 + 6H_2O$$

1. What is the effect of different concentrations of carbon dioxide on photosynthesis? Is there any effect of the presence of oxygen on the photosynthetic activity of plants?
2. Does photosynthesis proceed in artificial light?
3. Can photosynthesis proceed if the plant is exposed to artificial light for 24 hours?
4. Can photosynthesis proceed in artificial light of different colours? What effect would different colours of light have on the rate of photosynthesis as compared with the rate of photosynthesis in white light?
5. What are the optimum conditions of temperature, light, and CO_2 for photosynthesis in a given plant?
6. Leaves of green plants are the factories in which carbohydrates are manufactured. What relationships are there between the size and distribution of leaves on a tree? How do leaf structures of different plants appear to be adapted especially for photosynthesis?
7. Carbon dioxide gas passes through stomata to intercellular spaces of leaves from the atmosphere. In what ways do different kinds of distribution of stomata seem to affect the rate of photosynthesis?
8. Chlorophyll is a necessary pigment for photosynthesis. What may be the other pigments that are involved in the process of photosynthesis?

Plant Motions

Every plant shows some motions. Change in position may be observed at any region of the plant: root, stem, and leaf. The movements of the plants are the results of certain environmental conditions.

Tropic movements result in curvatures in plants. This takes place when a stimulus (such as light or contact) acts more powerfully from one direction than from another. In response, the plant (or a part of the plant) will turn when cells on one side elongate or grow at a faster rate than the cells on the opposite side.

In contrast to this, *nastic* movements do not change with the direction of stimulus. For example, flower buds open with the emergence of light, no matter from which direction it comes.

Tropic and nastic movements are permanent changes unless a new stimulus acts on the plant. In contrast to these movements are *turgor* movements which occur in plants for shorter periods and which are reversible. For example, sensitive plants show the folding of leaves and other parts when a stimulus

In some investigations students and teachers work in partnership of senior and junior researchers.

comes in their contact. After a few minutes the leaves and parts affected by the stimulus return to their former positions.

1. Roots are positively geotropic. Can roots be made to respond as though they were negatively geotropic by changing the direction of light or moisture?
2. Stems are negatively geotropic and positively phototropic. If light is exposed from the lower part of the stem will the stem respond by growing toward the light, against gravity?
3. What is the minimum intensity of light that will direct the movements of roots, stems, and leaves?
4. Can a tendril climb against the sharp edge of an instrument? Can a tendril climb against the smooth surface of a solid? Can this activity be influenced by raising the temperature?
5. If seeds are planted with the soil on one side containing a higher concentration of water than the soil on the other side, which direction will the roots grow?
6. How is the growth of roots and stems of germinating seeds affected when placed on a moving object (turntable)?

Plant Pigmentation

Do all flower pigments react to acids and bases by showing colour changes? What are the effects of different concentrations of acids and bases on plant pigments? Is it possible to tell the pH of soil by the colour of flowers of a pure strain of petunia? Can the pigments of plants be changed by the addition or removal of trace elements in soil?

Population Studies

The world human population is increasing at an astounding rate. If the present annual rate of approximately two per cent continues, by the year 2000 there will be more than six hundred crores people on earth—twice the population of 1965. The explosion of population is mainly the result of the decrease in death rate (due to the increase in medical knowledge) as well as an increase in the birth rate. For instance, in India the death rate fell from 27.4 (per thousand) in 1949 to 23 in 1963. The birth rate rose during this period from 39.9 to 42, and consequently the total population increased by 22.3 per cent.

Population dynamics is very much a part of biology. All organisms have the capacity to increase in numbers geometrically. (Theoretically, houseflies could fill the visible universe in just a few years.) But no organism realizes its full reproductive potential as there are numerous limiting factors in the environment that prevent uncontrolled growth. These limiting factors include food, oxygen, light, disease, war, predators, space, and toxic effects of body wastes. The biologist can learn much about general population growth through laboratory experiment, where the limiting factors are controlled.

A. Studies on human populations

1. What percentage of the total human population is constituted by females, and what percentage by males, in your beat (locality chosen for survey)?
2. What is the percentage of literate people in your beat?
3. How many boys and girls are receiving education at various stages? What is their percentage of the whole population?
4. What is the change of population in one year in your beat? From these figures can you estimate the change in total population?
5. What are the common diseases among the members of your beat?

B. Experimental studies on plants and animals

1. What kinds of growth curves of population are produced by yeast? by water fleas *(Daphnia)*? This study may be done by producing cultures in the laboratory.
2. What are the effects on growth curves of yeast, water fleas, or other laboratory populations when the amounts of food, oxygen, light, or other limiting factors are controlled?

For reference see:

1. Hazel W. Hertzberg, "Teaching Population Dynamics (esp. for India)." Population Instructional Materials Project, International Studies Program, Teachers College, Columbia University, New York, New York 10027.
2. Other publications of the aforesaid agency.

Poultry Farming

The success of a poultry farm depends upon several factors. Good management, resulting in profitable poultry, is only possible where the farmer has sufficient knowledge about housing, feeding, the rearing of chicks, and checking diseases. He must have specific knowledge of such details as optimum temperature and humidity ranges of poultry housing.

To a science student, poultry farming can be fascinating. It provides many challenging opportunities, such as the increase of egg production at low cost. The scientific farmer does not rigidly adopt the prescribed details of housing, feeding, and physical facilities of birds, but modifies these details according to the situation for ensuring more output at less input. He can devise his own waterers, hoppers for feeding, different methods of keeping optimum temperatures inside the house and a new menu for birds. Consider the following problems:

1. What are the weights and sizes of the eggs of different breeds? Are these dimensions uniform throughout the month and year?
2. Do the body temperatures of birds change with regard to time of day or season of the year?
3. Is the production of irregular eggs affected by lighting, the food that is provided, or the water supply?
4. What are the effects on health and egg production of reducing the space in the house for each bird?
5. Temperatures of 59°F. to 75°F. are preferred for good egg production. What would be the effect on the size of eggs, total production, and thickness of egg shells if the temperature were lowered or increased beyond this range? Can the effect of 1°F. change be detected?

6. What are the effects on the time for first egg production if the layers' mash (feed) is started earlier than the prescribed time?
7. What is the effect of providing dry food *vs.* wet food in summer and in winter on the egg production?
8. Which is the most suitable litter for birds: bhusa, paper shavings, wood shavings, or peanut shells? Which of the above is most effective as an organic fertilizer after being used for six months as litter?
9. Do birds eat the food that has been brushed away to the litter if it is again kept in hoppers? Is there any effect of this contaminated food on the egg production?
10. Do the birds eat food in the absence of molasses which is probably mixed to give a sweet taste to food? Does the absence of molasses affect the total egg production?

For reference:

1. *Poultry Guide,* monthly journal published from Prem Nagar Market, New Delhi-3.

Purkinje Effect

Why are automobile taillights red? Can this colour be seen best at night? The *Purkinje effect* notes that with a good level of illumination, the spectral sensitivity of the normal eye is greatest in the yellow-green region. As the illumination is reduced, the maximum sensitivity shifts toward the blue. This shift is called the Purkinje effect.

1. What is the most effective colour combination for signs to promote maximum readability?
2. Does it make any difference to the sensitivity of the eye whether the coloured light is emitted by a luminous source or reflected?
3. What colour or combination of colours should automobile taillights be for maximum usefulness during both day and night?

Reaction Time

Reaction time is the period between

How is the heart beat rate of a frog influenced by the calcium ion concentration?

detecting a stimulus and responding to it. One person may take comparatively little time between sensing the touch of a pointed needle to his skin and reacting with his hand or other body part to remove it—say, three-tenths of a second. Another person takes only one-tenth of a second in this process. Here, the reaction time of the second individual is less than that of the first. Reaction times differ among individuals. Some researchers have attempted to connect individual intelligence with reaction time.

Reaction time has been used to test potentials of automobile drivers, airplane pilots, factory workers, and astronauts. Many coaches have sought to discover future athletes by measuring the reaction times of young people.

1. Does difference in reaction times seem to be related to the sex of the subjects tested?
2. Do reaction times differ when all the senses, except the one being used, are effectively shut off?
3. To which of the basic senses is reaction the fastest?
4. How is the reaction time affected by repeating the stimulus-response over and over again?
5. What effect, if any, does drinking Coca Cola, coffee, or tea have on reaction time? What is the effect of smoking cigarettes or eating a candy bar?

Regelation

This thermal phenomenon is a direct consequence of the fact that the melting point of ice is measurably lowered by intense pressure. If ice at the normal melting point is subjected to great pressure it will become a liquid, and will refreeze when the pressure is removed. Thus the process of the melted ice freezing back again is termed as regelation.

1. At what velocity will a wire pass, by regelation, through a block of ice (Tyndall's experiment)? What relationships are there between the force exerted by the wire and the rate of regelation (passage of wire through ice)? Is the rate of regelation related to the diameter of the wire?
2. If steel ball bearings were embedded in the centre of blocks of ice, would their positions be fixed, or would they fall by regelation?
3. How is regelation related to the temperature of the ice?
4. The ability of skiers and ice skaters to glide smoothly over snow and ice is due to the melting of the surface ice by pressure. How is the coefficient of friction between ice and metal or wood related to pressure?
5. What is the temperature of the water produced when ice is put under pressure?
6. What solids other than ice exhibit the property of regelation?
7. What evidence supports and rejects the hypothesis that glaciers move by regelation?

Regeneration

All organisms are capable of regeneration. The degree of regeneration, however, appears to be quite variable in the animal kingdom. Man can regenerate, or replace, parts of lost tissue such as skin or bone, but the leg of a developed mammal cannot be replaced nor can the leg of a mammal give rise to the whole organism. Many phyla have amazing regenerative powers. Flatworms, starfish, hydra, and other simple organisms can be cut in two or more pieces with the result that each piece will develop into a completely normal organism. Embryos have high regenerative abilities or capabilities.

What questions can you ask about these phenomena?

1. Some regeneration of a frog leg can be stimulated by preventing the formation of scar tissue over the stump or, more effectively, by greatly increasing the nerve supply to the appendage.
2. Leg regenerative capacity is higher for spiders, insect larvae and pupae, and tadpoles than it is for the adults of frogs, insects, toads, and reptiles.
3. Altering the oxygen concentration at the regenerating surface affects the rate and structure of growth.

Respiration

The rate at which oxygen is consumed by a small animal such as a cockroach or an earthworm can be measured by placing the animal in a jar where absorbent paper that has been soaked in 0.4 per cent KOH is suspended. A one-hole stopper fitted into the jar holds a 0.2 ml. pipette containing one drop of dye at its distal end. As oxygen is consumed by the animal and carbon dioxide is absorbed by the KOH, the drop of dye moves down the pipette. A capillary tube may serve the purpose of the pipette.

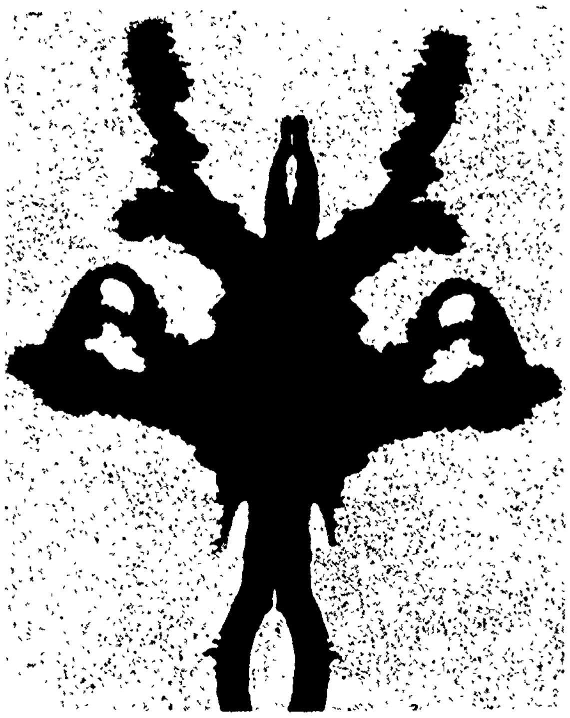
1. What are the changes in the amounts of oxygen consumed and the respiration rates of small insects when they are kept at different temperatures?
2. In what ways do changes in pressure influence the amount of oxygen consumption and rate of respiration of small insects?
3. Compare the amounts of O_2 used by different germinating seeds such as wheat and beans. Plot the graphs between the weights of seeds and the amount of O_2 used, and between the surface area of the seeds and the amount of O_2 used by them.
4. To what extent is the respiration rate of an insect affected by the plugging of individual spiracles?
5. In what way does the respiration rate relate to the weight of an individual?
6. Does an insect consume large quantities of oxygen after heavy exercise, as mammals apparently do?
7. How long are different individuals able to hold their breath? What relationships occur with respect to the height of the individual, chest diameter, and the length of time he can hold his breath?

Rorschach Ink Blot Test

The human mind is very complex. The behaviour of an individual in real situations provides the best clues as to how the mind interprets a situation and directs the individual's response. Individuals do not respond identically to identical situations. A whole range of behavioural responses is possible as when, say, a snake is observed on the road. Within this range of responses may be actions that reflect curiosity, disinterest, fear, terror, or even hunger. The behavioural response is based largely upon the past experiences of the individual.

To gain understanding of a personality—how an individual responds to a situation—psychologists have developed many kinds of tests that measure response to contrived situations. In one kind of test the situation is ambiguous or incomplete, and the subject is called upon to report what he perceives or how he would complete the situation. In the Rorschach Ink Blot Test subjects report what they see in the pattern that has been made by placing a blot of ink on a piece of paper, making a fold through it, and allowing it to dry. What do you see in the ink blot pictured here? What can you say about the nine boys who reported seeing an insect, circulatory system, bat, bird, grasshopper, plant, weed, developing embryo, and embryonic skeleton from this ink blot?

What do you see in this Rorschach ink blot?



Saliva

Think about limes! The chances are that when you do, you will notice an increased flow of saliva in your mouth. The average man secretes about 1500 ml. of saliva in twenty-four hours. Like most statistics about the average man, this one is subject to wide variation. Saliva is known to contribute to the digestion of foods. It is also an important factor in maintaining the health of the teeth and tissues of the mouth.

1. How do individuals vary in the amount of saliva secreted?
2. Is tooth decay related to some special characteristic of the individual's saliva?
3. What specific foods are digested by components of saliva?
4. Is saliva more or less effective when diluted with water?
5. What stimulates and/or slows the flow of saliva?
6. How does saliva compare with water and oil as a lubricant?
7. What is the effectiveness of spitting on one's hands before gripping a tool firmly or bowling a cricket ball?
8. How can it be demonstrated that spitting here and there is an unhealthy, harmful habit?

Sawdust to Sugar

Prior to World War I, German chemists who were searching for new sources of food discovered that wood can be converted into sugar by chemical reaction. While carbohydrates such as sugar are not scarce in this country at present, future generations will be faced with this problem.

In many parts of the world today protein foods are scarce. Recently, certain varieties of fungi were shown to be efficient in chemically converting some carbohydrates to proteins. Biochemistry may hold the key to the future nutrition of the world.

In addition to being a food, sugar can be the chemical forerunner of alcohols, aldehydes, and other materials.

1. What processes will convert wood into sugar?
2. What experimental conditions will produce a maximum yield of sugar from wood?
3. Can a catalyst be found for the conversion of wood to sugar?
4. Does it make a difference if the wood is in the form of chips, shavings, or sawdust?

School Days

The working hours of a typical higher secondary school are scheduled approximately from 7:00 a.m. to 12:30 p.m. in the month of March and onwards to the end of September, and approximately from 10:00 a.m. to 4:00 p.m. in the remaining months. Apparently the working schedule is fixed by the authorities, who take into consideration the comfort of the students. However, the best learning hours may not be the same as the most comfortable hours. The best learning hours may not change with the change of seasons. Similarly, vacations are mostly observed in the schools on the basis of tradition.

Serious suggestions have been made that a longer school day be instituted to keep up with the expanding amount of knowledge and skills required of high school graduates. These suggestions assume that an eight-hour day would permit one-third more learning than a six-hour day. This assumption may or may not be correct.

1. Most schools provide practice time to play football, volleyball, cricket, badminton, hockey, and other sports after school. Is this the best time for these activities?
2. Some students say they study more effectively and efficiently at night than during the day. Are these students actually more alert and active at night than in the morning?
3. Some schools conduct night classes. Are students mentally and physically equipped to do as well in these classes as in regular day classes?
4. Most schools have a tardiness problem. Why are students tardy? Are there ways to decrease tardiness? Is habitual tardiness an indication of some personal trait?
5. Many teachers feel that students do not utilize their full abilities immediately after lunch. Is this true? If so, how could one's after-lunch alertness be improved?
6. Specific behaviours of students may vary through the day and have implications for making school more effective. Does body temperature, pulse rate, reflex time, ability to memorize, and dexterous ability vary through the day? A quantitative study of any one of these may produce significant results. The results may not be the same for different individuals or age groups.
7. Do students always have the same ability to learn? Through the week? Through the month? Through the year?
8. Are student creativity and originality more active at certain times of the day, week, month, and year?
9. Many persons are easy to rouse from sleep in the morning and are "fast starters." Others are just the opposite. It has been suggested that this trait is due to a recessive gene. What evidence is there to test this hypothesis?

Science of Games

Have you ever thought about the principles of physics, physiology, and psychology that are fundamental to the playing of games? Consider the following problems:

1. Gilli-Danda: (A small piece of wood about six inches long and a stick about one and one-half feet long)
   a. What are the ideal relationships between the sizes, shapes, and the masses of "Gilli and Danda"?
   b. To what extent is the maximum distance travelled by the "Gilli" influenced by the striking force and the inclination at which the "Gilli" is struck?
2. Kabaddi: Can you select a "Kabaddi" player with regard to his dexterity, his ability to accelerate, and his acuity of senses as determined by tests?
3. Satoliya: (A game of seven stones placed one over the other)
   a. When the heap of stones is struck by a fast-moving ball, the stones are scattered. What is the relationship between the distance that a stone travels and the force applied?
   b. On striking the heap of stones with equal force but from varying distances and varying inclinations, how is the scattering of stones influenced?
4. Kites:
   a. What is the maximum sag of the span—the length of string between the kite and the person?
   b. Is the sag a function of the length of the string, the force of the wind, the mass of the string, the size of the kite, or the force of lift?
5. Cricket:
   a. Is there any relationship between the velocities of the moving ball when it leaves the bowler as compared to when it leaves the batsman?
   b. When the moving ball strikes the bat, can the motion of the ball be used for verifying the laws of reflection?
6. Ping Pong:
   a. Ping pong balls, after they have been played with, are sometimes found to attract small particles. If the ball becomes charged, what is the nature of charge?
   b. Compare the charge on a ball when it has been given equal strokes on sheets of metal, glass, and concrete.
   c. Is the bouncing percentage (see Bouncing Balls) of the ball influenced

by replacing the pad of the paddle with asbestos, plastic, metal, or sandpaper?

d. How does the spin given to a ball by the paddle influence the curvature of the trajectory of the ball?

7. How much weight is lost by a player or an athlete after a game of badminton, hockey, basketball, or a long race? What relationship exists between the strenuousness of the game or sport and the amount of weight lost?

8. How much momentum would an athlete develop in a high jump?

9. What changes in the athlete's breathing rate, heart beat, and body temperature occur after athletic activities?

Science Stamp Collecting

Attention stamp collectors! A stamp collection could be used as the basis for a science project. You have probably seen stamps showing the wide variety of flora and fauna native to the issuing nation. Examples are: a snail, Cuba; mushrooms, Poland; butterflies, Switzerland; or birds and mammals, Angola. Many of the stamps can be purchased from dealers for modest amounts or traded from philatelists.

A science-related specialized stamp collection could be made of mammals typical of geographical regions, animals of commercial importance, plants from which useful chemicals are obtained, or insects which are found throughout the world. It might be interesting to use an identification key to the objects on these stamps to check the accuracy of the printed identification.

Scientists have been honoured on many stamps. A specialised collection could be made of these with themes such as chemists, contributors to modern atomic theory, and pioneers in the science of electricity.

Useful references for specialised collections are "Standard Postage Stamp Catalog" and "Stamps of the World." A postage catalog may be had from the Post and Telegraph Department.

For an additional reference see Victor Showalter, "Scientists on Stamps, Reflections of Scientists' Public Image," *The Science Teacher* 31; 40/42 December 1964. (National Science Teachers Association, 1201 Sixteenth Street, N.W., Washington, D.C. 20036, U.S.A.)

Scientific Detective Stories

There are many kinds of scientists who in the course of their work recreate unavailable wholes from available parts. These wholes are theories, based on incomplete evidence and are subject to challenge by other scientists who may present a different picture of the whole, using the same fragments. The paleontologist will, on the basis of a few reptile bones, reconstruct the whole dinosaur, or, on the basis of a few fossil animals and the fossil imprints of leaves, will describe the climate and biological community of a region sixty million years ago. Archaeologists after excavating in ruins of an ancient city will, after studying fragments of pots, pictures, tools, and other artifacts, present a fairly complete account of life as they believe it to have been in that ancient society.

Remnants that a layman may think are useless may be very helpful in revealing much information. What is required on the part of the worker is patience and logical thinking. The secrets that may then be unfolded can be an important contribution to our knowledge. You too can be a scientific detective by reconstructing wholes from parts. Consider the following problems:

1. Can a bird's nest provide clues for describing the bird's characteristics? Can information about the structure and habits of a bird be deduced from the size, shape, locality, materials, and other observable clues to be found in a vacant nest?

2. What can you tell about the age, sex, temperament, complexion, height, health, and profession of a person if only a hand or any other part of his body is shown to you?

3. What can you infer about the formation of a rock when only a single piece of it is given to you?

4. What can you predict about the habitat and physiological activities of a plant if only detached leaves are given to you to observe?

5. What does a metallurgical analysis of the coins of a nation, past or present, reveal about the nation's technology, trade, values, or other history?

6. What can be inferred about the velocities of vehicles before collision on the basis of an examination of the wreckage and/or tyre marks on the pavement?

7. What can a photograph tell you about an individual?

8. What information about a lake can be inferred from a sample of sediment taken from the bottom of the lake?

9. What information about an individual can be gathered from an analysis of his blood?

Seed Germination

Seeds will begin to grow into new plants only after they have been exposed to the proper combination of moisture, air, temperature, sometimes light, and possibly other factors peculiar to the species of plant.

1. With other factors controlled what is the optimum temperature for the germination of seeds of one species?

2. What are the effects of light and darkness on germination of different kinds of seeds when all other conditions are controlled?

3. What would be the effect on germination if the seed coats were removed artificially before providing conditions for germination?

4. How much heat is evolved as a seed germinates?

5. How much pressure is exerted by germinating seeds? Do different seeds exert the same pressure provided other conditions of the experiment remain the same?

6. In what ways do the seeds change during germination?

7. Some farmers claim that seeds soaked in water before sowing germinate faster than those that are watered in the ground. In what way does the soak-

ing of bean seeds affect their germination rate? What types of growth curves would be obtained for seeds that have been soaked for different periods?

8. What would be the effect of an electric field on the growth of seedlings?

9. Air, proper temperature, and sufficient moisture are the chief demands of a seed to start germination. But seeds also get these same conditions inside the fruit. Why is the germination of seeds inhibited inside the fruit? Do the substances present in the fruit pulp have any inhibitory effect on germination?

10. What effects have germinating seeds upon one another? Will mixtures of different kinds of seed germinate as well as seeds sown separately?

Selenography

Selenography is the study of the surface "geography" of the moon. Centuries of remote observation and speculation about the features of the moon's surface have recently been replaced by close-up photographs taken by the spacecraft cameras of Ranger and Surveyor. Scientists are now able to study—still indirectly, but from a closer vantage point innumerable craters varying in diameter from about 150 miles to several inches. They can get a better view of expansive plains or "seas," mountain ranges and peaks, fractures that are as great as one-half mile wide and which reach to unknown depths. And they are pondering over giant streaks that radiate from tiny points on the moon's surface.

One very puzzling question is how were the craters formed? One theory claims they are of volcanic origin. Can you compare the features of volcanic craters on earth with those of lunar craters? Another theory points out that bodies striking a deep dusty surface produce craters similar to those seen on the moon. Bomb scars on the surface of the earth as viewed from the air support a meteoritic theory. Can this theory be tested in the laboratory, using projectiles as meteors which strike a surface that simulates the lunar surface? How do natural earth meteorite craters compare with lunar craters? Other questions about the moon which can be investigated include:

1. How deep are the lunar craters? How high are the mountains of the moon?
2. What known terrestrial mineral or minerals are of the same colour by reflected sunlight as those of the moon?
3. Why are the lunar streaks only visible during the full moon?
4. What portion of the tidal phenomenon on the earth is caused by the moon?
5. How can atmospheric tides on the earth be measured?
6. Does terrestrial magnetism vary with the distance of the moon from the earth?
7. How can the reflecting power of the moon or any satellite be used to calculate its temperature?
8. From your direct observation can you predict the times of the next lunar and solar eclipses?
9. Could one or more satellites be designed to provide illumination for night vision? Would a continuous day upset the biological balance of the earth?

Research in genetics can be carried out in your garden where pollination can be controlled carefully.

Sensory Stimuli

Most of what we know about the universe has been acquired by man through his senses. Everything we know about the world in which we live has come to us through our senses or indirectly through instrumental extension of the senses.

A normal person's range of hearing varies from 20 to 15,000 vibrations per second. This range varies among individuals and with age.

The range of stimulus intensity for other senses is not as well understood as it is for sound. A study of any one of the senses from either a psychological, chemical, physical, or physiological point of view can lead to the exploration of many interesting phenomena.

1. What is the minimum concentration of salt in water that you can detect by taste? How does this value compare with minimum concentrations for sweet, sour, and bitter tastes?
2. How sensitive is the eye to small differences in brightness of luminous objects? Does the same sensitivity exist for all colours?
3. Does the presence of one taste substance mask the presence of another, and if so, how?
4. Insects, bloodhounds, and other organisms reportedly are able to detect very small traces of odour-causing substances. How sensitive are people to odours? What differences are there among individuals in this respect?
5. Is the efficiency of people who work in the atmosphere of an unpleasant odour significantly reduced?
6. Can people become accustomed to distracting stimuli such as noise and odour and thereby be less affected by them?
7. What is the minimum temperature difference detectable by humans?
8. Can the sense of taste be used to determine end points in acid-base titration? Can the sense of smell be used?

Shale

Shale is soft sedimentary rock generally originating from hardened mud. In many parts of the country shale deposits are several hundred feet thick. Although shale consists mainly of fine hydrous aluminum silicate grains that are useful in the manufacture of bricks and tiles, a wealth of fossil fuel, uranium, and other valuable minerals are known to be present in shale. Since easily obtainable natural resources are rapidly being depleted, we must soon turn to sources of chemical energy and to minerals in which the expenditure to win them is closer to the power value of the fuel or the value of the mineral.

1. After detailed examination, what can you deduce about the geological origin of the shale in your region or shale obtained from state geologists in other regions?
2. What materials are present in the shale and in what quantities?
3. How many British Thermal Units per tonne are there in this shale? How does it compare with other shales?
4. What are the qualities of bricks, tile, pottery, and cement that are made of this shale?

Sleep

Sleep is a phenomenon related more to the functioning of the brain than to physical rest. Kleitman, a physiological psychologist, put his view that a person gets sleep when the activity of brain (posterior part of the hypothalamus) decreases due to less excitation from the outside world's disturbances and when internal stimuli such as muscular pains of gastric contraction decrease. Although the muscles may relieve their tensions during sleep, sleep without doubt is accompanied by the loss of consciousness which is purely a brain function. The condition of sleep has been identified as being separate from the condition of anesthesia because in the former case the person can be made to awaken by producing a strong sensory stimulus outside the body.

Some investigations of the process of sleep can be conducted by observing the behaviour of large numbers of people and animals as they sleep and/or by interviewing persons after they have awakened. The generalisations on this phenomenon must be made only when the sampling is large and the experimental conditions are carefully controlled.

1. What are the most satisfactory sleeping patterns for individuals—eight hours, six hours, four hours sleep in 24 hours, or a series of short naps? What are the effects of lack of sleep or of too much sleep?
2. When is sleep the deepest—early, median, or late—during the period of sleep? Does this vary among individuals?
3. How do reaction times of different persons vary upon waking? At the time of retiring?
4. Can you learn while asleep?
5. What changes in body functions (heart beat rate, breathing rate) occur during sleep?
6. Is the best sleeping position for everyone horizontal?
7. Is there any truth to the belief that worries disturb sleep? Is it then correct that the more worries, the less sleep?

Soft Drinks

Carbon dioxide gas is dissolved in almost every soft drink. The solubility of carbon dioxide is directly proportional to the amount of pressure applied. Carbon dioxide forms carbonic acid in water solution. When the pressure inside the bottle is reduced by removing the lid, carbonic acid decomposes. Carbon dioxide then bubbles through the beverage and passes out of the bottle.

The degree of carbonation differs from one brand of soft drink to another. Such comparison should be made for a fixed volume of beverage. Permanence of carbonation might be estimated quantitatively by measuring the rate of carbon dioxide release at a standard temperature and pressure.

1. After being opened, do certain soft drinks retain their carbonation longer than others?
2. Is there any difference in the degree of carbonation of various soft drinks?
3. Is there any negative catalyst that will slow the decomposition of carbonic acid to carbon dioxide and water? To be useful, the substance obviously could not be toxic.

Soil Fertility

Soil is an exceedingly complex and variable sediment. It originates mainly from the decomposition and disintegration of bedrock through the action of wind, rain, glaciers, temperature changes, and other weathering agents. The upper portion of the soil, called topsoil, is composed of the more highly decomposed mineral matter and contains varying quantities of water-absorbent organic matter, *humus*. Below the topsoil is the subsoil, usually less fertile, but supplying minerals and water to deeply rooted plants. Soil types seem to be greatly influenced by temperature, rainfall, and organisms that interact with an inorganic base that is present.

1. Can a satisfactory soil be synthesized by pulverizing the bedrock in your area and blending it with a water-absorbent organic material?
2. One characteristic of poor soil is its impermeability to water and air and its hardness, which resists root growth. Soil conditioners are used to correct this characteristic. Three kinds are available. One is organic material such as peat or coffee grounds; another includes inorganic materials such as sand and vermiculite; and a third includes the synthetic and semisynthetic conditioners such as IBMA (the half ammonia, half-amide salt of isobutylene maleic acid), Krilium, X 2, and X 19. Try each of the three types of conditioners in exposed subsoil. Which treatment is most effective?
3. Where the minerals, gases, and water in the environment of plant roots can be carefully controlled, can soilless plant culture (hydroponics) yield larger and healthier crops than soil gardening can produce?
4. An essential soil element for

Compare the refracted images of the wall and window as seen through the empty portion of the flask with those seen through the water-filled portion of the flask. What experimental questions about optics can you ask about this phenomenon?

plants is nitrogen. From which of the following ions is it most effectively utilized: ammonium, nitrite, nitrate, cyanide, or nitride?

5. Are there any variations in the rates of capillary rise of water in various core samples of soil? What is the most effective hoeing depth for a particular plant in a clay soil?

Solid Creepers

You have seen things creeping (moving slowly in contact with a surface). Everyone is familiar with green creepers (ivy). You have seen them creeping up a wall, a tree, or a frame. When you dip a piece of chalk stick or a piece of blotting paper into water, the fluid (water) is observed to creep upward.

Have you ever seen solid substances creep, much like liquids? Dissolve ammonium chloride into a small quantity of water to give a concentrated solution; filter if necessary. Place the solution in a clean beaker and allow it to stand for several days. You will notice salt particles creeping up the walls of the beaker.

1. Which chemical in your laboratory is the best creeper? Do all substances creep?

2. How is the creeping influenced by weather conditions? Is the rate of creeping influenced by the nature of the solvents and the different materials of which the vessels are made?

3. Is the rate of creeping constant? Are the rates influenced by the degree of inclination and the nature of the surface?

4. How is the rate of creeping influenced by a fan? Is creeping affected by adding dye, ink, milk, or oil?

Solutions

When two substances are mixed and form a homogenous medium the product is called a *solution*, the *solute* having dissolved in the *solvent*. The combination of solute and solvent may be any one of the following: Gas in gas, gas in liquid, gas in solid, liquid in gas, liquid in solid, liquid in liquid, solid in liquid, solid in gas, or solid in solid.

In the process of dissolving, the particles of the solute are attracted by the molecules of solvent. These attractive forces may be of various strengths. If the attractive forces of the solvent are strong enough to overcome the attractive forces that hold the particles of the solute together, the substance will dissolve.

1. How do the solubility *vs* temperature curves compare for sodium chloride, table sugar, and copper sulphate?

2. How is the temperature related to the solubility of a gas in a liquid and a liquid in a liquid?

3. What are the times necessary to form solutions when one gram of powdered sodium chloride and one gram of sodium chloride (in large crystals) are put in containers of equal amounts of water? What are the timings taken by other solutes treated in similar ways? What relationship exists between the rate of solubility and the surface area of the solute?

4. How much time does sugar take to dissolve in 500 ml. of water when it is agitated, as compared with when it is not agitated?

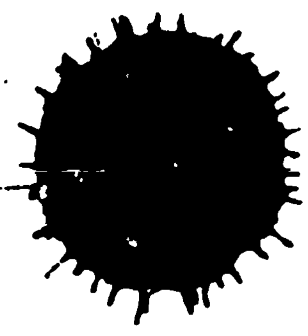
5. Every liquid solvent has its own boiling point and freezing point. Similarly, every solid solvent has its own melting point. How are the boiling points, freezing points, and melting points of solvents influenced by the addition of solutes?

6. Does the interaction between solute and solvent result in a rise or fall of temperature?

Splashes and Spatters

Have you ever carefully examined the stain produced by a drop of ink that had fallen several decimetres on to a hard flat surface? The figure shown is an enlargement of the record of a drop of ink that had fallen from a height of one metre on to a sheet of paper.

Count the number of rays that radiate from the spatter. In what ways do the number of rays vary with the distance the drop falls? Can the height of the fall be related to the length of rays, the forms of rays, and the diameter of the main body of the spatter? How does the surface tension of the liquid affect the form of the spatter patterns? What are the most probable shapes of the ink drops at the instant of spatter on the paper? (Ideas of the form could be expressed with modelling clay.) How do the spatter forms of ink drops differ from the splash form produced when a small solid sphere collides with still water? How is the pattern of splash related to the nature of the surface on to which the substance is dropped?



This is the spatter pattern of an ink drop that had fallen one metre. What would be the patterns of spatters dropped from heights other than one metre?

Starch

A starch molecule consists of a number of glucose units attached to each other by oxygen linkage to the 3, 6 carbon atoms. The general formula of starch can be represented as $(C_6H_{10}O_5)n$.

Starch forms the major parts of our food. Most plants have their food stored in the form of starch which is prepared through the plant's photosynthetic activity. Major sources of starch for humans are cereal grains, rice, and potatoes. Starch is a basic raw material for the preparation of alcohol. It is also used in textiles for stiffening and finishing clothes. In the paper industry starch is used in the sizing and thickening of paper, and it is also a good adhesive.

1. In what way do the structures of starch grains differ in food plants such as wheat, potatoes, rice, oats, and corn?

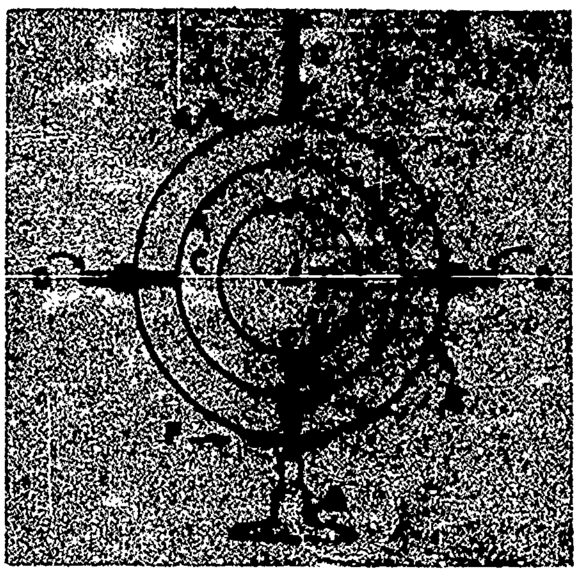
2. What proportions of water and different types of grain starch are suitable for the gel preparation used in stiffening clothes?
3. How does starch glue compare with other kinds of glues as an adhesive?
4. With the iodine test (the blue-black colour with starch), test for the presence of starch in the following:
   a. Pastes and glues.
   b. Kinds of foods.
   c. Different types of leaves with and without chlorophyll.
   d. Different woods and fibres.
   e. Various parts of plants.
5. At what rates do the starches of potato, rice, maize, and wheat change to glucose under the action of saliva?

Static Electricity

When one substance is rubbed against another, mechanical energy is transformed into other forms of energy such as heat and static electricity. One method of producing static electricity is to rub plastic with hair, or glass with silk. The plastic becomes negatively charged leaving the hair positively charged, whereas the glass loses electrons to the silk and becomes positively charged. Similarly two metals that have the same temperature develop a potential difference when rubbed together. The friction of metal on metal explains the buildup of electrical charge on automobiles in motion.

Large amounts of electrical voltage are produced in the atmosphere when particles are rubbed together by violent drafts of wind that develop in thunderstorms. And in laboratories, electrostatic machines depend upon friction for the production of static charge.

1. What common substances other than plastic, glass, hair, and silk can be used to generate static electricity?
2. Does a balloon filled with CO_2 and another balloon filled with ordinary air show similar properties when each is rubbed?
3. How can the charges built up in a terelyne shirt be measured? What kind of charges do you get?



A metal sphere (A) is fixed on an insulated stand (B). Two metal hemispheres (C) are attached with insulated handles (D) and cover the metal sphere (A). The hemispheres are then covered by two more metal hemispheres (E); the lower hemisphere with a hole rests on an insulated support (F); the upper hemisphere is attached with an insulated handle (G).

4. What pair of metals develop the highest potential difference when rubbed together?
5. How much mechanical energy is converted into how much heat energy when two substances are rubbed together?
6. When a positive or a negative charge is applied to a group of long dry hairs that have been tied together at one end, the hairs are mutually repelled and stand out. Does the amount of separation of two hairs reflect the quantity of the charge?
7. Charge always resides at the outer surface of a metal hollow sphere. This statement may be tested by a system of metal hollow spheres, one placed inside the other (see figure), each sphere being separated from the others by air which acts as the dielectric. Will a charge remain on the inner sphere? If the charge on the inner sphere were reversed, would the behaviour be the same?

Strength of Glued Joints

Glues are the products of hydrolysis of proteins, derived from either plants or animals. The slaughter house provides many types of glue made from hides, bones, fish, and blood albumen.

All glues do not have the same binding power. Many environmental factors, such as temperature and rate of air flow which are useful in drying, influence the joining capacity of glues. The comparative strengths of glues may be found by measuring the amount of force that must be used to break the joints when similar wood blocks are joined with different glues.

1. Keeping the drying time constant, what is the effect of very low and high temperatures on the joints of blocks in which different glues have been used? What is the most effective temperature for each glue?
2. How much time is required for the drying of glue to give the strongest possible joint?
3. Would similar results occur if metal were glued to metal or plastic to plastic instead of wood to wood?
4. Does mixing two types of glue produce a stronger joint than one type of glue alone?
5. What special preparations (physical or chemical) of the surfaces to be joined would enhance the strength of the joint?
6. Could a detergent be added to the glue to strengthen the joint?
7. Separation of joints may be caused by either the glue particles separating from each other or by the glue particles separating from the wood particles. How does the separation of joints occur in your blocks? This study may be done by observing the separated pieces under the high power lens of a microscope.
8. How do glue joints compare with rubber cement joints, paste joints, or iron nail joints?

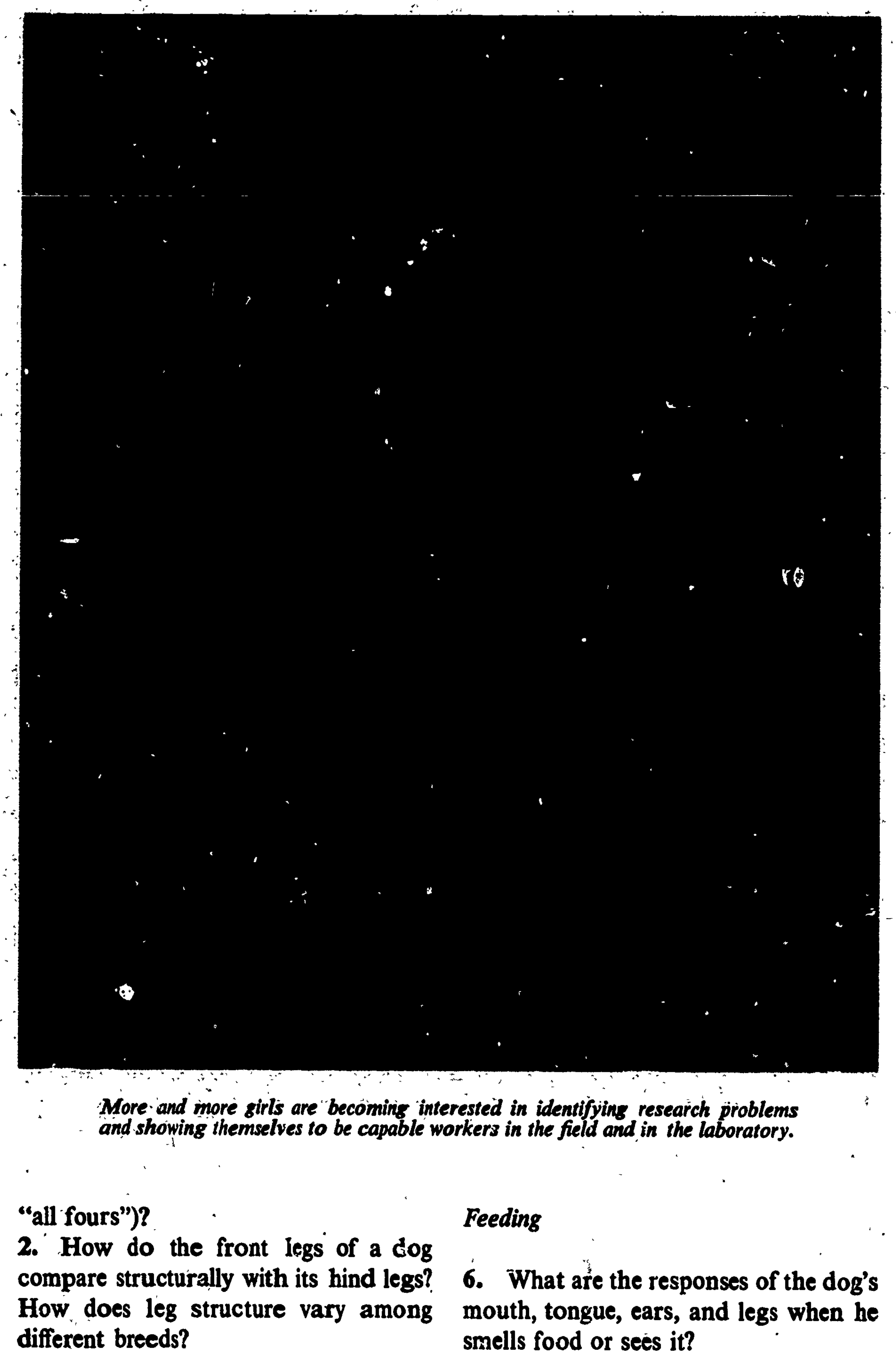
Studies on Inactive Life or Life in Suspension

Collect a jar of sediment from a dried out pond or pool. Add sterile water to some of the sediment in an aquarium. Observe and identify the forms of plants and animals that appear. Examine the dry sediment and identify the forms of specific organisms that did not dry out. Can the specific adaptation of each organism to adverse environmental conditions be discovered by keeping them in various unfavourable conditions? Are the adaptations of organisms to dry conditions comparable to their adaptations to other adverse conditions, such as winter temperatures? How long a dry spell can mosquito eggs tolerate? Through how long a winter can a frog hibernate? What extremes of temperature, age, exposure to acids, bases, and salts, and deprivation of oxygen can seeds, spores, eggs, or cysts tolerate?

Study of Cilia

Cilia are delicate, hair-like cellular structures in unceasing vibrating motion. They are common to most animals and some plants. Cilia function as a means of locomotion in organisms such as paramecia, vorticella, opalina, and stentor. The process of ingestion of food is carried out with the help of cilia in some organisms like the paramecium. In vertebrates, the cilia direct eggs into fallopian tubes and clear the bronchi of congesting particles. The rhythmic action and structure of cilia can be observed under a microscope.

The flow patterns of ciliated tissue on the tongue of a frog can be observed by plotting the paths taken by small pieces of cork placed on the tongue. Ciliated cells are fascinating to observe and are a source of puzzling questions for the researcher in physics, chemistry, or biology.



More and more girls are becoming interested in identifying research problems and showing themselves to be capable workers in the field and in the laboratory.

Study of Dogs

Dog is man's "best friend." But few people have paid much attention to the dog as an object for scientific investigation. Consider the following problems related to the anatomy, physiology, and behaviour of this animal.

Motion

1. What is the sequence of leg movements of a dog as it walks? Does this sequence alter during running? How does the sequence of leg movements of a dog differ from the sequence of leg movements of other animals such as cats, cows and man (when crawling on "all fours")?
2. How do the front legs of a dog compare structurally with its hind legs? How does leg structure vary among different breeds?
3. How do the legs of a dog compare with the legs and arms of men, goats, and cats, with respect to homologous structures like elbows, digits, palms, heels, knees, and wrists?
4. How does the speed of a dog compare with the speed of a human? How fast does a dog run 100 yards or one mile?
5. At what rate does a dog swim?

Feeding

6. What are the responses of the dog's mouth, tongue, ears, and legs when he smells food or sees it?
7. Can a dog be conditioned to appear for feeding at the sound of 2 rings of a bell? Can he be trained to quit eating at the sound of 4 rings of a bell? What other stimuli (audio, visual, tactile) can be used to condition the dog?
8. What are the behaviours shown when food is taken away from a pet dog and a street dog?
9. Which sense is more powerful in

bringing a dog to food—smell, hearing, or seeing—or are all equally powerful?

10. Will a dog regularly overeat? Has it the ability to select a balanced diet from a wide variety of foods?

11. How do you know when a dog is hungry?

12. How are the different teeth of a dog adapted to process different kinds of food?

13. How do the teeth of dogs and other mammals compare in kind, distribution, and structure?

14. Exactly how does the tongue function while the dog drinks?

Growth

15. At what rates do puppies grow? What kinds of growth curves are produced when weight, length, and diameter are plotted against time in weeks?

16. At what rate does hair grow? How does the texture of a dog's hair change with the age?

17. What exactly does the size of a puppy's paw tell you about the eventual size of the dog?

Respiration, Circulation

18. How does the rate of breathing of a dog differ before and after a long race?

19. How does a dog lose its body heat during summer?

20. How does heart beat rate relate to the size and age of a dog?

21. How does the rate of heart beat change with exercise? How does it differ from the heart beat rate of humans, cats, and goats?

Adaptations

22. Male dogs are found to mark their territorial boundaries by urinating at short intervals. Identify the area of the territory of a dog. Does more than one dog occupy the same area? Is there any relationship between the space covered and the size of a dog's family?

23. What are the actions of ears, tail, mouth, and other body parts while a dog is:

a. greeting his master;
b. confronting a stranger;
c. being scolded;
d. pursuing prey;
e. defending his territory against intruders.

Subjective Time

Time is measured by physical devices that are notable for their constant and regular operation. The human "clock" often seems to proceed in jumps. We have all heard someone say, "Is it time to go already?" Likewise we have experienced time flying or dragging. The time we perceive without reference to a clock is often called subjective time.

1. Can people learn to estimate short time intervals accurately?
2. What changes, if any, in one's physical environment cause great differences in estimated and measured time?
3. Are time estimates affected when one, two, three, or more of a person's senses are actively engaged in receiving stimuli?
4. Does the time sense change as a young person matures?

Sugarcane

Sugarcane is an important commercial crop of India. It is grown mostly in irrigated areas having an adequate water supply. Its acreage is mostly concentrated in Uttar Pradesh and Bihar.

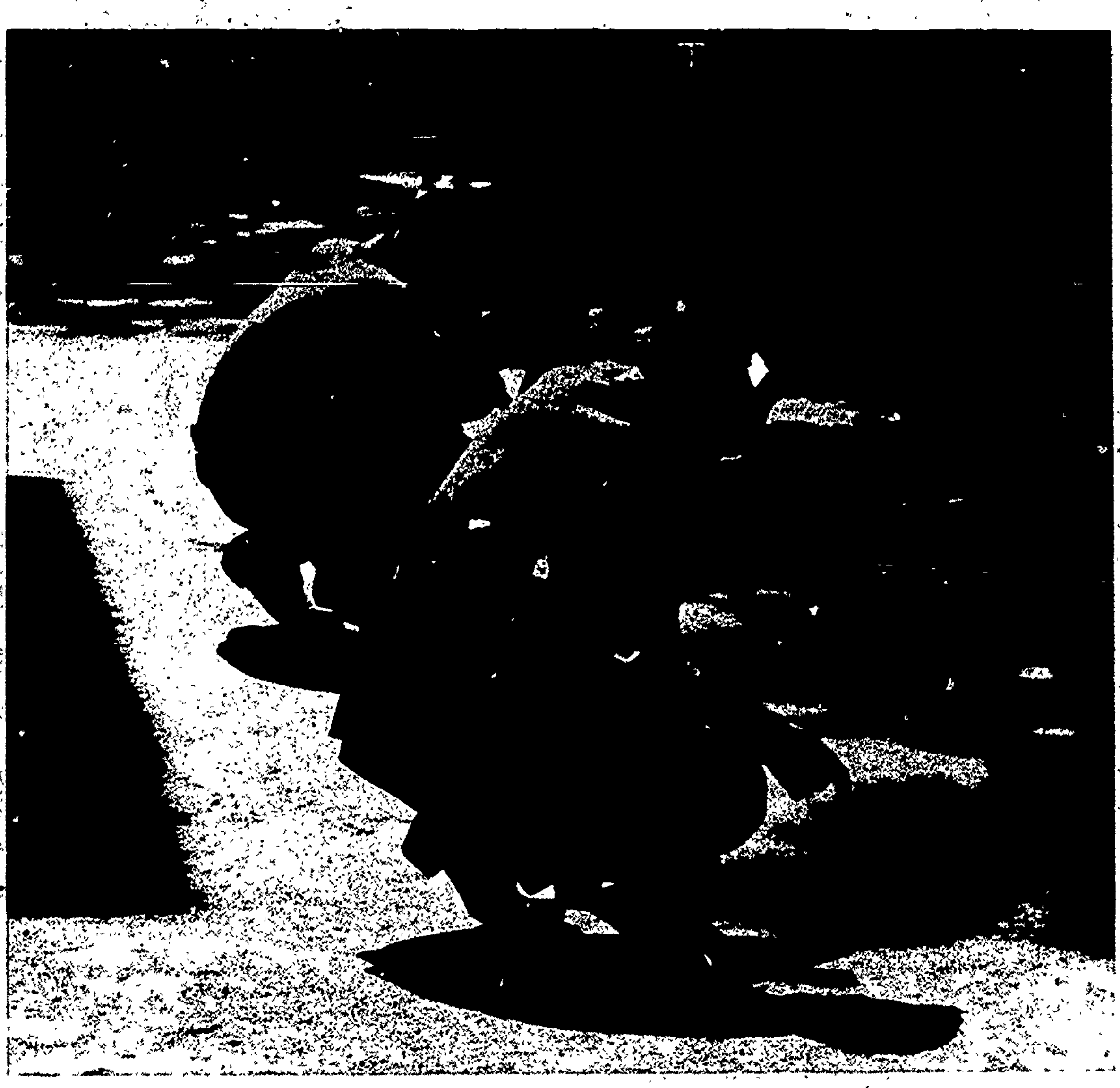
Compared with other crops, the percentage of germination of sugarcane is low. The quality of the cuttings used for planting and the planting conditions both influence germination. Germination increases progressively at temperatures above 70°F., while optimum temperatures are 80°–90°F. Having adequate moisture (15%) in the top six inches of soil is also important at planting time.

Intense light favours tillering while low light intensity favours growth of the main plant. The reason for this is that the production and flow of substances that regulate growth and inhibit the sprouting of lateral buds are stimulated in the absence of light. Therefore, there is a more rapid growth of sugarcane during the night than during the day. Soil moisture also plays a dominant role in growth.

Low temperatures favour sugar storage in the plant. Heavy application of nitrogen decreases sugar content in cane and the same is true of excessive irrigation. Post-monsoon irrigations, however, help in increasing the sugar content in cane.

Spraying the sugarcane crop with hormones like 2, 4-D (sodium salt) exerts a favourable influence on sugar content.

1. How do the germination tillering, and growth of one set of plants soaked in water before planting differ from other sets that have not been soaked in water before planting?
2. How do the germination, tillering, and growth differ in plants grown from cuttings taken from the upper part of the sugarcane and from cuttings taken from the lower part of the same plant?
3. In Northern India the sowing of sugarcane takes place one month later than in Southern India. This delay is due to the fact that the planter must wait until the kharif is harvested. If sugarcane were planted (in the North) in an experimental plot at the same time it is normally planted in the South, how would it differ from normally planted Northern India sugarcane?
4. In what ways do tillering and growth differ in plants planted under sheds and in direct light?
5. What would be the effect of artificial light on flowering of sugarcane?
6. How does the nature of the soil affect the germination of sugarcane?
7. What is the effect of high humidity on the growth of sugarcane?
8. Is sugar accumulation in the cane dependent on the presence of light? How is growth affected by the presence or absence of light?
9. What would be the effect on sugar accumulation in cane if the gap between the maximum and minimum temperatures during 24 hours were wide?



Shade under a heavily foliated tree in bright sunlight may contain real images of the sun.

Sun Pictures

If we look under a group of trees on a sunny day, we see on the ground a number of spots of irregularly scattered light in the patches of shade. Some spots are large; some are small. These spots of light may be termed "sun pictures."

The explanation of this phenomenon is to be found in the fact that the sun is not a point source of light. Any very small opening between the leaves causes a small, well-defined real image of the sun to appear in the shade. Another small opening gives an image at a different location. Sun pictures are of varying degrees of brightness.

If you hold a pencil between the sun picture and the opening in the leaves so that the shadow of the point of the pencil is on the sun picture, the specific opening in the leaves can be located by extending upward the segment of the line from picture to pencil.

1. Do all the sun pictures have the same shapes?
2. How do the patterns of sun pictures vary when viewed in the morning, at noon, and in the evening?
3. Can a device be developed to measure the height of a tree, using sun pictures?
4. Does the image of the sun formed at various distances under a shaded tree depend upon the shape of the aperture? (A sheet of thin cardboard with different shapes of aperture such as circular or triangular, held up so that the sun's image falls on a well-shaded spot, may be used to answer this question.)
5. Intercept one of these (sun picture) images by a piece of paper held at right angles to the rays. Raise the paper gradually higher and examine the image.
   a. Does the shape of the sun picture remain the same upon interception?
   b. What relationship can be developed between the height of the paper (as lifted up) and the shape or size of the sun picture?

Symbiosis

Symbiosis is the association of two different organisms in which one or both may derive benefit from the association. The association may be either between plants, or between animal and plant, or between animals. Common examples include lichens, euglena and zoochlorella, leguminous plants' root nodules and nitrogen-fixing bacteria.

Parasitism is the kind of symbiosis where one partner (parasite) loses independence while the other partner (host) loses nutrients. Dodder and intestinal worms are examples of parasites.

1. How do the alga and fungus of one lichen react when brought together after separate culturing?
2. What sort of symbiotic reaction would occur in a lichen if it were subjected to darkness for about one week?
3. What sort of association is found between dodder and the tree on which it grows?
4. What would be the effect on the growth of dodder if it were detached from its host?

Synthetic Rubber

A type of synthetic rubber known as a polysulfide polymer can be made easily in the laboratory. The process does not require high pressures or high temperatures. The only reactants are a saturated solution of sulphur in 4 per cent sodium hydroxide solution and 1, 2-dichloroethane (ethylene dichloride).

The polymer is formed by placing the two immiscible liquids in contact with each other at a temperature near 60°C. The product of the reaction is a light-yellow rubbery substance. When washed free of excess sodium hydroxide, the synthetic rubber can be handled without any harmful effect.

This polysulfide polymer has two shortcomings. First, it has a very strong, disagreeable odour. Second, it slowly loses its rubbery character over a period of time.

1. What improvements in the final product could be made by carrying out the polymerization in varying conditions such as high temperature, or violent agitation?

2. Can the final product be changed by using different reactants (e.g., 1, 2-dibromoethane)?

3. What effect on the final product could be brought about by adding a substance such as a salt to the reaction mixture?

4. How do the properties of this synthetic rubber compare with the properties of natural rubber produced from the latex sap of Calotropis or the common roadside rubber tree, Ficus?

Tensile Strength

When a stretching load is applied to materials such as wire, paper, concrete, beams, iron bars, etc., the particles that hold the material together experience tension. On increasing this load (force) gradually, a point is reached at which the material will be pulled apart.

The force (per unit of cross sectional area) required to break the material is called the *tensile strength* of the material. The tensile strength of various materials can be determined experimentally with a handmade device.

1. How do the tensile strengths of the metals of which wires are made compare?

2. What are the tensile strengths of fabric fibres such as terelyn, cotton, and silk?

3. How do the tensile strengths of male and female hair compare? Is the tensile strength of a person's hair related to his age?

4. Do the tensile strengths of body, beard, and head hair vary?

5. Are the tensile strengths of hair of the same length from cows, bulls, buffalo, horses, and donkeys the same?

6. How strong is a strand of spider silk?

7. Are the tensile strengths of various substances influenced by rise of temperature or degree of wetness?

A library search is often an important part of a scientific investigation. Certain types of projects can be conducted entirely in the library.

Time and Clocks

Time is a unique phenomenon. A definition of time is very difficult to write although we all experience its passage; it is easier to measure time. All we need is a process or event that repeats itself regularly. By definition, a precise clock is unvarying in its periodic motion.

The standard unit for this motion is 1/86,400 part of a mean solar day. The *mean solar day* is based on the apparent motions of a fictitious mean sun. Since the actual solar day is not constant throughout the year, more dependable standard sources of periodic motion must be used. Scientists have investigated the internal motions of crystals, molecules, and atoms, and their search continues for the most reliable sources of periodic motion.

1. What is the greatest accuracy that can be obtained from such timekeepers as hour glasses, drip cans, burning candles, and chemical, mechanical, electrical, atomic and piezoelectric clocks?

2. How do various makes of mechanical wrist watches vary within the normal extremes of temperature? Does a wrist watch subjected to the greater centrifugal effects at the equator maintain the same accuracy as it would at the North Pole where the centrifugal effect is slight?

3. How many different kinds of time-telling devices can you construct in your laboratory in which the reference event (as in the burning of a candle) or the periodic motion (as in a lunar clock) is different from the standard solar day?

4. According to the theory of relativity, if two identical clocks, A and B, are synchronized and then A is accelerated and brought back for comparison, A will record a shorter time interval than that shown by clock B. Do the time pieces of astronauts reflect this "clock

paradox" phenomenon?

5. With what accuracy can the human mind judge intervals of time? Is it true that persons confined in darkness cannot distinguish minutes from hours, or hours from days after a period of time?

Tooth Decay

Tooth decay usually occurs as a result of the bacterial fermentation of carbohydrate particles that are left between the teeth after eating. Fermentation is so rapid that generally within an hour corrosive acid can be detected. The acids are produced by bacteria that grow in a soft deposit (called dental plaque) that surrounds the teeth. The first action of acids takes place on the inorganic substances of teeth, *enamel* (outer coat of teeth), and then starts dissolving dentin and pulp (organic portion of teeth).

The large number of bacteria in the mouth does not necessarily indicate the possibility of tooth decay. Lactobacilli, acid-producing bacteria, have been found in the mouth as early as six months before actual decay in a tooth has started.

1. How strong are teeth? How much force can a tooth support vertically? Horizontally? What extremes of temperature can a tooth endure? How do the acid resistances of teeth compare?
2. How do habits of smoking and chewing petals affect the multiplicity of the bacteria in the mouth?
3. How efficient are the different available brands of toothpastes in stopping tooth decay? Suggest a good brushing technique.
4. What are the causes of good dental health in persons who are free from tooth decay? Is there any hereditary explanation for this?
5. How does the population size of bacteria in samples of saliva fluctuate with the kinds of food a person has recently eaten?
6. How do the bacterial counts and pH of the mouth of one individual vary with health, age, and time of day?
7. What changes occur in the tooth as a person becomes older?
8. What tooth diseases can be observed in animals other than man?
9. Is there any truth in the advice not to take cold things after hot things or vice versa because this might damage the teeth?

Toys—Science

A number of toys and curiosities on the market today present some challenging problems.

1. Sling Shot
   a. What is the relationship between the stretching force and the distance travelled by stones projected from a sling shot?
   b. How is the distance travelled by the projectile influenced by the inclination of the stretching arms? Is the velocity of the stone constant when it is projected at different inclinations?
2. Air Gun
   a. What are the muzzle velocities of the various air guns available in the market?
   b. To what height and how far can a gun project its shot? Is there any relationship between the trajectory and the maximum distance travelled by the projectiles of an air gun?
3. Bow and Arrow
   a. What are the relationships among the size, shape, and mass of the arrow and the bow?
   b. How does the design of an arrow influence its trajectory?
4. Paper Airplanes
   a. What kind of paper is most suitable for making a paper airplane?
   b. How do air currents influence the flight path of the airplane?
   c. How does the design of the airplane influence its manoeuvreability?
5. Jump Rope
   a. What parts of the body and which senses are involved when using the jump rope?
   b. What are the ideal characteristics of a rope for jumping?
   c. How fast can one operate a jump rope?
6. Wheel and Stick
   a. How do the dimensions of the stick affect the motion of the wheel?
   b. How slowly can you drive a wheel with a stick?
   c. How does the inclination of the stick influence the motion of the wheel?
7. Bicycle
   a. How is the strength of the wheel related to the spokes?
   b. How is the air pressure in the tubes related to the traction?
   c. How fast can one drive a bicycle? Can this limit be increased by developing a device that will decrease the mechanical advantage?
   d. With what maximum force is traction obtained when a bicycle is drawn over greasy, dusty, or icy surfaces?
8. Sound Makers
   a. What is the frequency of a whistle that you blow?
   b. A whistle made from a green leaf produces a certain note. How is this note influenced by the dimensions of the leaf and the nature of the leaf?
   c. How do temperature, pressure, and humidity influence the sounds of musical instruments?

Unilateral Electroplating

A thin piece of metal such as brass, when electroplated with nickel on one side will bend. In this case the curvature is such that the nickel is on the convex side of the bent strip. The stresses that cause this bending are present when a strip is plated on both sides but the stresses oppose each other, and no bending occurs. These internal stresses are very troublesome in commercial electroplating because the plating tends to crack and peel away from the base metal.

1. How does the voltage used during electroplating affect the internal stresses in the plated layer?
2. Are the internal stresses dependent on plated metal, base metal, temperature of plating bath, or other variable conditions?

3. Can substances be added to the plating bath that will increase or decrease the stresses in the final product?
4. Can practical application be made of this phenomenon?

Vapour Pressure

The vapour pressure of a substance (solid or liquid) is the pressure exerted by its vapour when in equilibrium with the substance. The vapour pressure of a pure substance varies only with the temperature.

The vapour pressure for most substances is not immediately apparent. If a careless person heats a can of beans without puncturing the lid, however, a violent explosion will certainly convince him that vapour pressure is a very real force. The rapid evaporation of gasoline and the characteristic odour of some plastics is further evidence that molecules escape from liquids and solids. Even "permanent" materials such as rock, metal, and glass exert a vapour pressure and evaporate, though at a very slow rate. This tendency of molecules to escape is a crude definition of *vapour pressure*.

Many relatively simple instruments can be made to measure relative vapour pressure and form the basis for vapour pressure studies. One way to determine absolute vapour pressure is to introduce a small amount of the substance into the closed end of a barometer tube and note the change in the height of the mercury in the barometer.

1. How is the vapour pressure of a liquid affected by solutes?
2. How does the vapour pressure of a super-cooled solution compare with a solid state? (Water and a solution of sodium thiosulfate are easily super-cooled).
3. Are there specific relationships among vapour pressure, heat of fusion, heat of vaporization, and other similar properties?
4. What is the vapour pressure of naphthalene?

What mathematical relationships can you find between boiling points and pressure?

Variable Friction

Whenever one object slides across another, the force of friction tends to retard the sliding. Edison found that when electricity flows between a metal strip and a piece of paper soaked in salt water, a decrease in friction between the two results.

1. Would the same effect occur if dry carbon paper were used in place of the soaked paper?
2. Would a solution other than table salt work as well or better?
3. What effect does varying the voltage have on the friction?
4. Are there practical applications of this phenomenon?

Visual Inversion

The image that falls on the retina of the eye is inverted. Apparently the brain turns this image over so that we perceive objects as being "right-side-up." It is said that if a person were to receive non-inverted images on the retina, the brain would adjust to the change, and in time the images would appear right-side-up. With the assistance of an optometrist, a set of inverting glasses might be constructed that will enable an investigator to test this hypothesis.

Water

1. How does water taken from wells, ponds, rivers, lakes, the sea, rains, and sewage canals compare with distilled water with respect to specific gravity, pH, amount of dissolved solids, amount of dissolved air, sediment, and electrical conductivity?
2. How wet is water? The phenomenon of surface tension can be measured by determining how much force is required to pull a wire ring, immersed in the liquid, through the surface membrane. Quantitatively compare the wetness of soapy water, oil, alcohol, and mercury. How is the wetness of a liquid related to the number of drops (from a medicine dropper) in a cubic centimetre of the fluid?

3. Over a period of a season, how do the temperatures of a lake correspond with the temperatures of the atmosphere? Using jars that open and fill with water at certain depths, determine a profile of the temperatures of a lake.
4. What are the necessary physical and chemical conditions of water to sustain various forms of aquatic organisms?
5. Humans are capable of detecting temperature changes of the order of 1/10°F. How reliable is a human finger as a water thermometer? Can a finger be "trained" to measure accurately water temperatures?

Water Rocketry

At the present time, rocket propulsion is the only method by which spacecraft can be put into orbit or sent to another planet. It is not possible for you to experiment with full-sized rockets, but experiments with miniature rockets can be exciting and safe if conducted properly.

Water rockets are easy to construct and are excellent for experimentation. Such rockets carry potential energy in the form of compressed air, which expels a jet of water rearward. Reaction forces propel the rocket forward. Since you use a hand pump (cycle pump) to load the rocket with compressed air, you can control the amount of pressure used.

To construct the water rocket, take a round-shaped, empty can or talcum powder can which can withstand pressure (preferably a plastic can). Close the mouth with an air-tight, one-holed rubber stopper through which there is a delivery tube connected to a hand pump. Put some water in the can, replace the cork, and pump in some air. Don't stand too close to the rocket. Release the cork and carefully observe what happens.

1. What is the maximum height that your rocket attains? How much time does it take between launch and impact?
2. Would twice as much water send a rocket twice as high or some other height?
3. What combination of pressure and volume of water produces the highest flights?

Could the eye and mind adapt to an upside down world? At what rate does one's reading speed increase when words are held upside down?

4. Water rockets have tail fins that can be bent so that the rocket spins in flight. Does spin (or lack of it) affect the flight of rocket?

Wells

1. What different kinds of minerals and rocks are encountered during the process of digging a well in your locality? How do the findings compare from well to well? Can a profile (a cross section) of the rock formations from the surface of the land to the water table be drawn?
2. Assuming that the distance from the ground to the surface of the water in a well is the depth of the water table, is the depth of the water table throughout the region constant? How does the water table vary over the period of a year?
3. Daily variation in the height of water in a well may be caused by tides or earthquakes. Can a daily variation in water height be detected?
4. What percentages of minerals are present in well water? At what critical point is water too "hard" or too saline for agricultural use or for drinking?
5. How do the temperatures of well waters compare? Is there any relationship of temperature to depth?
6. What is the average amount of water that a well can provide in a single day?

Whirlpools

Whenever a bathtub drains, a whirlpool often results. Whirlpools in the Northern Hemisphere are said to rotate counterclockwise, and those in the Southern Hemisphere, clockwise.

A simple apparatus could be devised to permit a study of whirlpools on a laboratory scale.

1. Do all the whirlpools in your area rotate in the same direction?
2. What force or forces cause whirlpools?
3. Does fluid density affect whirlpool formation?
4. Is the ratio of diameter to depth the same for all whirlpools?

Wood

The word wood is frequently applied to fuel, which in this case means forest products cut to a size suitable for burning in stoves. The word may also apply to finished products such as boards, beams, and joists. In botanical terms, wood means that part of the stem, trunk, or branches that is composed of the water-conducting xylem and associated fibres. In perennial plants these cells form considerable mass, as in trees, shrubs, and vines.

Generally woods are divided into two main classes, the soft woods and the hard woods. The structure of the wood is a very important factor in determining its ultimate use.

1. How do the woods of your region compare in terms of hardness, density, tensile strength, porosity, and microscopic structure?
2. How much water is contained in a cubic foot of wood? Test at least three varieties of wood in your region. How much water can wood imbibe?
3. Which of the local woods is best suited for the production of charcoal?

Research can often be conducted effectively through a team approach in which each member makes a significant contribution.

4. How are the properties of boards influenced by the manner in which they are cut?

5. What are the ages of the jungles in the region of your home?

6. What can the study of the growth rings of a tree tell you about the climatic history of the region in which it had been growing?

Additional Questions in Biology

1. *Facial vision* is a term used to explain a person's ability to avoid walls and other obstructions at night or when blindfolded. How accurate is a person's facial vision?
2. Does aspirin in water prolong the show-life of cut flowers? Can other substances be found to accomplish this?
3. Should the stems of roses be cut back in the fall after frost, in the spring before the emergence of new growth, or never?
4. Why do popcorn and, to a lesser degree, other varieties of corn pop?
5. Pyrethrum is an insecticide powder extracted from certain chrysanthemums. Do these flowers affect insects that contact them?
6. Is there such a physiological phenomenon as a "second breath"? To what extent is the "second breath" a psychological development?
7. What is the optimum sugar concentration in which pollen grains will germinate?
8. Do insects see colours?
9. How much pressure and heat can be developed by germinating seeds?
10. What is the effect of light intensity variations on the opening of the stomata of a leaf?
11. Do the stomata close in a dust storm or in rains?
12. Should smokers wash their hands before handling tomato plants to ensure the protection of the tomato from tobacco virus?
13. Is subject matter that is easily learned also easily forgotten?
14. Are fingerprints, lines in the palm of the hand, or other wrinkles in the skin indicative of some characteristic of the individual? Are these specific patterns or types inherited?
15. Many people have increased their reading speed by special training and practice. Can a person's listening speed be improved beyond the rate to which he is accustomed?
16. Do people make their best physical and mental efforts when alone or with other people? Does competition have a stimulating or depressing effect on people?
17. Does everyone exhale the same amount of air?
18. What birds migrate to and from your geographical area? What birds pass through your geographical area during migration and are not permanent residents?

Is there a relationship between the surface area of a leaf and its rate of transpiration?

Additional Questions in Chemistry

1. What change, if any, is observable in the chemical make-up of rain from one rainstorm to another?
2. Does magnetized iron have different chemical properties than unmagnetized iron?
3. To what extent does the natural acidity of wood increase the corrosion of iron filings under damp conditions?
4. Can an alloy be made of a metal and a compound, e.g., lead and lead oxide or nickel and cobalt chloride?
5. What volume and kind of gas is coconut charcoal capable of adsorbing?
6. Why does the odour of coffee differ from the taste of coffee?
7. What substances are found in rain that are the result of man's being on earth?
8. Is carbon monoxide slowly oxidized to carbon dioxide by atmospheric oxygen?
9. Does tobacco contain the same proportion of nicotine from seedling to mature plant?

Many experimental questions can be asked during regular school practicals.

10. Can effects of nicotine be avoided in tobacco without removing the nicotine from the plant?
11. Does the pH of a water solution affect the germination of seeds?
12. It is usually assumed that a solution with a pH of seven is less irritating to the skin than are the solutions of higher or lower pH. Is this true? (The pH of human blood is about 7.2.)
13. In tyre-recapping shops, a considerable amount of buffing dust, finely powdered rubber, is thrown away. Is there any practical use for this dust?
14. Fermentation of carbohydrates is a common process for producing ethanol. What strain of yeast is capable of producing the highest concentration of alcohol?
15. What are some of the effects of high pressure on chemical substances?

Additional Questions in Physics

1. Which instrument is more accurate for determining 'g' acceleration due to gravity, a simple pendulum or a physical pendulum?
2. Why and how do stones skip on water? Will stones skip on sand?
3. If a large rubber sheet is stretched on a frame, can depression in the sheet approximate a gravitational field when marbles are rolled across it?
4. Can the thermal conductivity of liquids be predicted on the basis of molecular or ionic constituents?
5. Does the exact pattern of tyre threads make a difference in the tyre's performance?
6. Is there a limit to the electrical voltage that can be produced by cells in series?
7. Is there a limit to the intensity of magnetic or electrostatic fields that can be formed?
8. Does a spinning cue ball colliding with a target pool ball produce postcollision paths of both balls that are different from that predicted for normal (nonspinning) collisions?
9. Is there minimum voltage at which electroplating will occur?
10. How do changes in environment affect the rate at which concrete hardens?
11. Can Ohm's law be modified to describe the voltage, current, and resis-

tance relationships of conducting solutions?

12. How does temperature affect the properties of balls?

13. The accuracy of the ordinary electric clock depends on the constancy of the A.C. frequency maintained by local power stations. How constant is the A.C. frequency maintained in your community?

14. Electricity has a tendency to leak at high electric pressure. Can an electric bulb be lighted when placed under electric pressure without any connections?

15. How is the density of a substance influenced by temperature?

16. Which substances show a decrease in volume on heating and an increase in volume on cooling?

17. How do the thermal and electrical conductivities of hair compare?

18. How deeply will ink ordinarily penetrate into paper?

19. Can you develop a device to verify the laws of reflection and refraction other than the corpuscular theory?

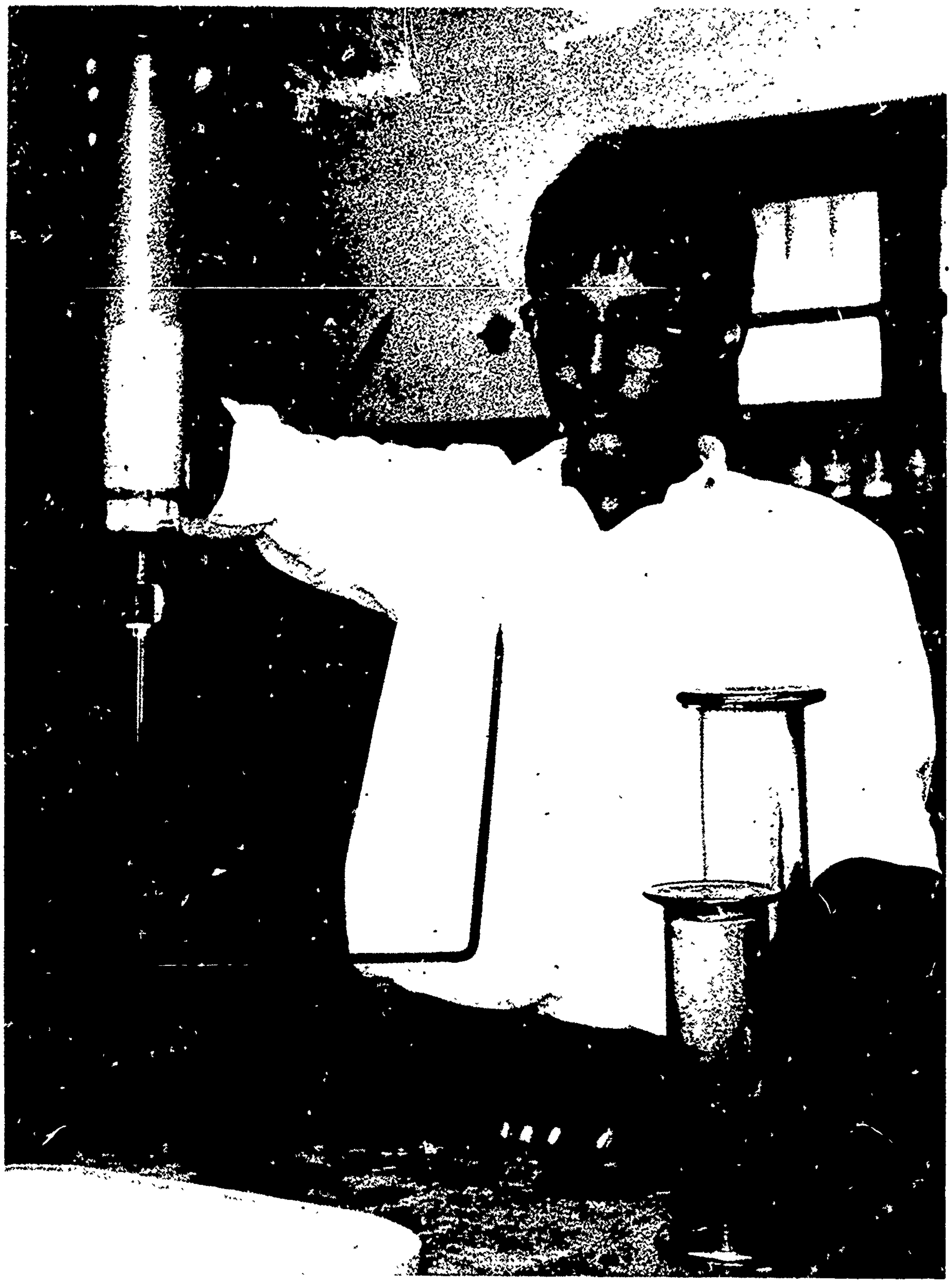
20. Sometimes thick clouds are seen in the atmosphere; still there is no rain. How can you make the clouds release rain?

21. Why are sparks produced when flint and steel are struck together? What are the temperatures of the sparks?

22. Some types of shoe soles squeak when the wearer walks across certain types of floors. Why? Can some additive be found to diminish this effect?

23. How do samples of sediment collected in stream beds compare, in terms of the size of the grains and the shape of particles, with samples collected from the flooded plain of the same stream?

24. Can the conditions of the interior of the earth be duplicated in the laboratory?



Hydrogen diffuses from the glass cylinder through the clay cup faster than the air can diffuse from the cup into the cylinder. The pressure that builds up within the clay cup forces the fluid out of the constricted end of the glass tubing in a jet stream. How can this demonstration apparatus be changed so that the pressure of diffusion can be measured?

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